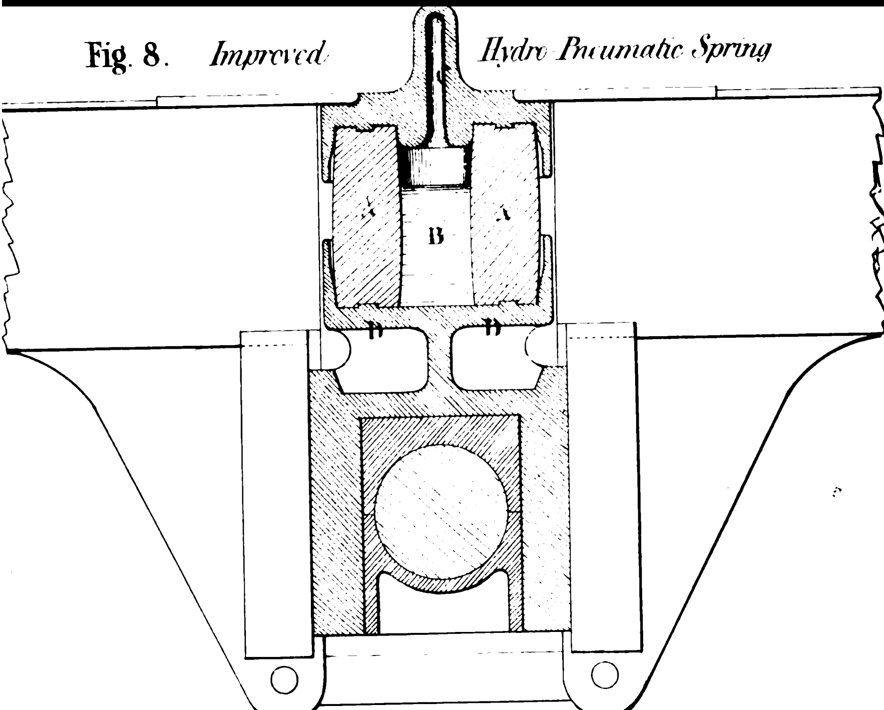
Fig. 8. *Improved Hydro Pneumatic Spring*



Proceedings of the Institution of Mechanical Engineers

Institution of Mechanical Engineers (Great Britain)

INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

1853.

PUBLISHED BY THE INSTITUTION,

54, Newhall Street, Birmingham.

1853.

BIRMINGHAM:
PRINTED AT M. BILLING'S STEAM-PRESS OFFICES, 74, 75, AND 76, NEWHALL STREET.

PROCEEDINGS.

The Sixth Annual General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, January 26th, 1853, Robert Stephenson, Esq., M.P., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL,

1853.

The Council have the satisfaction of congratulating the Members on this occasion of the Sixth Anniversary of the Institution, upon the advancement and progress of the Institution, and its increasing efficiency and success.

The number of Members, &c., for the last year is 204, of whom 13 are Honorary Members, and 3 are Graduates.

The financial statement of the affairs of the Institution for the year ending 31st December, 1852, shows a balance in the Treasurer's hands of £173 1s. 3d., after the payment of all accounts due to that date. The Finance Committee having examined and checked all the receipts and payments of the Institution for the last year, 1852, have reported that the following balance sheet, rendered by the Treasurer, is correct.

(See Balance Sheet appended.)

The Council have the pleasure of announcing that the following Donations to the Library of the Institution have been received during the past year :—

C. Cowper, on the Great Exhibition Building of 1851, from the Author.
D. K. Clarke, on Railway Machinery; from the Author.
G. D. Dempsey, on the Machinery of the Nineteenth Century; from the Author.
W. Johnson, on the Patent Law Amendment Act; from the Author.
W. Spence, on the Present State of the Law of Patents; from the Author.
Journal of the Society of Arts.
Minutes of Proceedings of the Institution of Civil Engineers.
The Artizan Journal; from the Editor.
The Civil Engineer and Architect's Journal; from the Editor.
The London Journal of Arts; from the Editor.
The Mechanics' Magazine; from the Editor.
The Mining Journal; from the Editor.
The Practical Mechanics' Journal; from the Editor.
Engravings of New Express and Luggage Engines; by Mr. J. E. McConnell.
Improved and Ordinary Safety Lamps, and new Carriage Lamp; by Mr. Samuel Thornton.
Busts of the Duke of Wellington and Sir Robert Peel; presented by Mr. Robert Rawlinson.
Bust of Tredgold; presented by Mr. Jonathan D. Ikin.
Bust of Murdoch; presented by Mr. J. E. McConnell.

The Council refer with great satisfaction to the practical value and interest of the Papers that have been presented to the Institution during the last year, and express their thanks to the Authors of the Papers for the valuable information they have furnished to the Institution. The Council confidently anticipate continued advancement in the importance and number of the communications brought before the Institution, and they have promises of several valuable Papers for the ensuing year.

The following Papers have been read at the Meetings in the last year:—

On an Improved Boiler for Marine Engines; by Mr. Andrew Lamb, of Southampton.

On an Improved Break for Railway Carriages, &c.; by Mr. William Handley, of London.

On a Continuous Expansion Steam Engine; by Mr. James Samuel, of London.

On a New Mode of Measuring High Temperatures; by Mr. John Wilson, of St. Helens, Lancashire.

On the Expansive Working of Steam in Locomotives; by Mr. Daniel K. Clark, of Edinburgh.

On a New Portable Lifting Machine; by Mr. J. E. McConnell, of Wolverton.

On the Mathematical Principles Involved in the Centrifugal Pump; by Mr. Andrew J. Robertson, of London.

On the Expansive Working of Steam in Locomotives; (second paper), by Mr. Daniel K. Clark, of Edinburgh.

On the Expansion of Isolated Steam, and the Total Heat of Steam, by Mr. Charles W. Siemens, of London.

On Bourdon's Metallic Barometer, Indicator, and other Applications of the same principle; by Mr. Charles Cowper, of London.

On a New Improved Screw Propeller; by Mr. George H. Bovill, of London.

On a New Direct-Acting Steam Pump; by Mr. William K. Whytehead, of London.

On Improved Fire-Brick Gas Retorts; by Mr. J. E. Clift, of Birmingham.

On the Arrangement of the Materials in the Blast Furnace, and the Application of the Waste Gases; by Mr. Samuel H. Blackwell, of Dudley.

On Improvements in the Construction and Materials of Railway Waggons; by Mr. William A. Adams, of Birmingham.

On a New Self-lubricating Axle Box for Railway Engines and Carriages; by Mr. Paul R. Hodge, of London.

On a Self-Acting Spring Crossing Point for Railways; by Mr. Paul R. Hodge, of London.

The Council are desirous particularly to call the attention of the Members to the importance of the preparation of Papers on some engineering subjects that have come under their attention, for the purpose of advancing the objects of the Institution, by the communication and interchange of information and experience upon improvements and practical working, and extending the utility of the Institution, in promoting improvements and affording opportunity for carrying out practical investigations and experiments. A list of proposed subjects for Papers is appended, and the Council invite communications from the Members and their friends on these and other subjects that will be serviceable and interesting to the Institution; and they also invite the Members to aid in the formation of the collection of mechanical models and drawings, and books for the library, with indicator-cards from steam engines, and statistical returns of the working of engines, &c., so as to extend the utility of the Institution.

The Officers of the Institution, and five of the Members of the Council in rotation, go out of office this day, according to the rules, and the ballot will be taken at the present Annual Meeting for the election of the Officers and Council for the ensuing year. An increase in the number of Vice-Presidents, from three to six, was proposed at the last meeting of the Institution, to be submitted to the decision of the Members at the present Annual Meeting.

THE CHAIRMAN congratulated the members on the eminent success of the Institution; during the six years since its foundation it had been steadily increasing in prosperity, in the importance of the proceedings, and the number of members.

The transactions during those years showed a list of papers including many important subjects; many of them subjects of great interest, occupying the attention of the profession. Amongst the papers he might allude to two that occurred to him: Mr. Blackwell's, "On Iron Furnaces," and Mr. Clark's, "On Locomotive Engines," which he considered very valuable contributions to this Institution, and to science in general. He hoped the members would keep up well the supply of practical papers; and in addition to such papers, he wished to call the attention of the members to the value and

desirability of supplying to the Institution reports on any successful experiments that came under their attention and experience. He also considered that it would be a great advantage not to confine these reports to successful, but also to report on unsuccessful experiments; the best way to succeed was to be acquainted with the failures that had occurred. Failure implied an erroneous judgment on some one or more points; and well-recorded facts, whether of success or failure, were most valuable, as the means of rectifying and avoiding in future the erroneous judgments that had been previously formed; and he hoped that all the members would not hesitate to report any failures that occurred to themselves, or that came under their observation. He remembered that one of the first mechanical works that had been put into his hands by his father was the "Repertory of Inventions," and he especially explained to him the reasons why he considered different inventions would not answer; more was learned often from failures than from successes.

On the motion of Mr. S. Thornton, seconded by Mr. A. Allan, the Report was received and adopted.

Mr. E. Marshall moved a vote of thanks to the Council and Officers of the Institution, for their services during the past year; the motion was seconded by Mr. R. Williams, and passed.

The CHAIRMAN moved, according to the proposal made at the last general meeting, that the number of Vice-Presidents be increased from three to six; and the motion was passed unanimously.

The CHAIRMAN then announced that the ballot-papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year.

President:

ROBERT STEPHENSON, M.P., London.

Vice-Presidents:

CHARLES BEYER, Manchester.
WILLIAM FAIRBAIRN, Manchester.
JAMES E. MCCONNELL, Wolverton.
JOHN PENN, London.
ARCHIBALD SLATE, Dudley.
JOSEPH WHITWORTH, Manchester.

Council:

Samuel M. Blackwell, Dudley.
John E. Clift, Birmingham.
Benjamin Fothergill, Manchester.
Richard Peacock, Manchester.
J. Scott Russell, London.

Treasurer:

Charles Geach, M.P., Birmingham.

Secretary:

William P. Marshall, Birmingham.

The Chairman announced that the following new members were also elected:—

Francis Adkins, Birmingham.
William G. Craig, Newport.
Edward Duclos de Boussois, Paris.
George England, London.
Joseph Fraser, Berkswell.
Henry Marten, Wolverhampton.
Edward J. Payne, Birmingham.
Joseph P. Ronayne, Cork.
John Ross, Birmingham.
Edward Slaughter, Bristol.
Thomas Spencer, Westbromwich.

The Chairman observed, that as he had the honour to be re-elected as President of the Institution, he should be happy to serve during the next year; after which time it was proposed that the President should be changed annually, or at least every two years, according to the plan that was now generally adopted, and was found to work most advantageously in other institutions, such as the Geological and the Astronomical Societies, the Institution of Civil Engineers, &c. He was satisfied this change would be conducive to the permanent interests of the Institution; but in any case, whether in or out of office, he should have great pleasure in testifying the interest that he felt in the Institution, by doing all in his power to promote its welfare, and advance its objects.

The following paper, by Mr. John McConochie, of Wednesbury, was then read:—

ON AN IMPROVED RAILWAY CHAIR.

The consideration of the best means of increasing the durability of that part of the permanent way of railways which consists of its Rails and Chairs, has received much attention of late from practical engineers, the subject having been brought more prominently into notice by the wear and tear, or destruction that takes place in this portion of railway plant; the double-headed rails becoming in some places unfit for use within five or six years from the time they are laid down. The cause of their so soon becoming deteriorated seems mainly to arise from the insufficiency of the common description of Chair. This insufficiency is clearly proved by the thousands of tons of rails that are now being returned into different works as old iron, the bottom head being almost as sound as when rolled, except having indentations every three feet where the Chairs have been fixed; the rails being thus so much damaged as to be unfit for reversing, according to the original intention. Such being the case, it proves the importance of using some description of Chair which will support and secure the rail without injury to its durability.

The subject of the present Paper is an improved Railway Chair, which it is believed will meet this requirement, and increase the durability of the rails from 25 to 50 per cent.

Figs. 1, 2, 3, 4, and 5, Plate 1, represent this improved Chair, as supplied to the Liverpool, Crosby, and Southport Railway. These views show the nature and object of the Chair; it consists of two parts, first, the body of the Chair A, and secondly, the abutment-piece B; the key C is made of either wood or iron, but the former is preferred; a space D, of about 1-8th of an inch is left between the lower head of the rail and the sole of the chair; the fillet E fits loosely into the groove cast in the abutment-piece, which prevents the possibility of its being driven out of the Chair. The weight of the Joint Chair here shown is 35lbs., and the weight of intermediate Chairs for the same section of rail averages 26lbs., which is not more than the weight of the ordinary

description. When it is desirable to remove the rails, the operation is as follows :—the lock key C is driven out, which allows the rail to rise vertically out of the Chair, carrying with it the abutment-piece, so that the operation of turning the rail is performed as easily as when the common description of Chair is used. In the latter the support of the rail is entirely dependent on the wooden key, whereas the improved Chair forms of itself a self-acting fastening for the rails, thereby offering considerable facilities for laying in, repairing, or relaying the road. Besides, as trains may pass over them immediately the rail is laid-in, before keying up, it shows the comparative unimportant office the wooden key has to perform in these Chairs, in comparison with those in ordinary Chairs. In the latter the keys require continual replacing and supervision, which forms a considerable item in the maintenance, both in superintendence and materials; in the improved Chair the office of the wooden key is simply to lock the rail in the Chair, thus forming a more complete bond between the rail and the sleeper.

It may be observed at the same time, that several of these Chairs have now been in use three or four months without any keys; the lateral force of the abutment-piece serving to some extent as a key to them. This point of superiority of the improved Chair over those in common use should not be overlooked, for if the keys in the latter are omitted or get loose and work out, it is to the peril of the trains that pass over them; while in the new Chair it has been proved that such an omission is not attended with any danger, except under extraordinary circumstances, where there may be a liability of the earthwork slipping.

That this improved Chair adds to the stability of the road and stiffens the rail, is proved by the experiments which are appended to this Paper.

The prominent feature in the improved Chair consists in its preserving the lower head of the rail from injury, while the upper one is in use, by supporting the rail as shown in the drawing. The object being to obtain the maximum amount of wear out of a given quantity of material, by wearing down successively the top and bottom surfaces of the rails.

The durability of the rails greatly depends on the strength and steadiness of the fastenings, which is one of the advantages of this Chair, from the fact of downward pressure tending to tighten its hold on the rail: this is an important point, as theoretically, Chairs to be perfect should be as tight to the rails as if they formed a part of them. The fact of the ordinary Chairs being an inefficient fastening, has led to the abandonment in many instances of the double-headed section of rail, notwithstanding its many advantages when used in combination with transverse sleepers. In the opinion of the writer, by the adoption of the present method of fishing at the joints, combined with better intermediate fastenings than the ordinary Chair, the double-headed rail and transverse sleeper cannot fail to outlive all the expedients which have been resorted to of late years to supersede this construction of permanent way, which is common to the Northern Districts, the fatherland of railways.

The ordinary fastenings are loosened and deteriorated principally by the alternate upward, downward, and lateral pressure, from the deflexion of the rails between the supports. In the improved Chair, the combined action of the lock-key and abutment-piece prevents this injurious action going on, as in the ordinary Chair, in the comparative ratios (as shown in the experiment) of from 50 to 100 per cent., according to the different weights applied.

With the ordinary Chair, the tendency of the rail to get bent and crooked operates very materially to lessen its durability; for in some instances, even if the lower head were not notched, it would not be fit to reverse unless straightened, and the fibres consequently disturbed, &c.; but with the improved Chair the liability to get bent is greatly lessened by the additional stiffness these Chairs give to the rail.

With the view of securing a more uniform road, and preventing the possibility of the Joint Chair canting, it is recommended that a sleeper be laid lengthways underneath the Joint Chair, as shown at AA in Figs. 13 and 14, Plate 3.

Another modification of the improved Chair is shown in Fig. 8, Plate 1. It presents more bearing surface to the rail than any other Joint Chair in use, consequently it greatly strengthens the

rail at the joint. It differs from the Chair already described, in having two abutment-pieces instead of one, which are made fast by wrought-iron keys, as shown at I I: when the keys are backed, the rail can be lifted vertically out of the Chair.

The results of some experiments made some time back, by Mr. James Samuel, upon the rails of the Eastern Counties Railway, by interposing gold-leaf between the rail and the chair, showed that the amount of surface in contact between the rail and their ordinary intermediate Chairs was 1½ sq. inches. This appears a liberal calculation, but if we take it as an approximation, it gives a result of rather more than 6 to 1 in favour of the improved Chair; for as the two jaws of the Chair are equal unitedly to 12 inches in length, and as the width of their contact with the neck of the rail may be taken at ¾ of an inch, the total bearing surface is 9 square inches, instead of 1½ inches. Therefore if we take the weight of an engine driving wheel, hammering along at the rate of 30 or 40 miles an hour, to be equal to a force of nine tons, this would throw a pressure of 6 tons on the square inch on the 1½ square inch of rail in contact with the sole of the common Chair; but it would only amount to 1¼ tons per square inch on the underside of the head of the rail in the improved Chair; so that, while the former pressure is sufficient to indent the rail, the latter will probably prove quite harmless.

Objections have been raised to this Chair on the ground that the tendency of the jaws will be to tear the head off the rail. This would be the case if the jaws were tapered to an edge, instead of being rounded to the same curve as the underside of the head of the rail, the part in contact with it. With an edge they would by degrees work their way into the head of the rail, until, lamination taking place, a separation of the top from the bottom part of the rail would ensue. The writer understands that something of this sort took place on the London and Birmingham Railway with some of the first Chairs laid down on that line. In these Chairs a portion of the weight was carried on the sole of the Chair, as in ordinary Chairs at the present time, but in order to give greater support to the rail, the arm of the Chair opposite the key bore right against the head of the rail; it was found, however, that as soon as the under head began to bed into the Chair, the whole of the weight came on the top

of the arm or side of the Chair, against which arm it was backed up, though inefficiently, by the key on the other side of it, but the Chair being only the same width as the common one, did not present much bearing surface to the rail; the weight then bearing on such a narrow surface caused the head of the rail to be indented and injured, and, consequently, the attempt to support the rail at these two points at the same time was abandoned. The failure of these Chairs, however, cannot be taken as an argument against the success of this improved description. For example, a strong pair of shears, while its edges are square and sharp, will cut through the thickest boiler-plate; to this the Chairs just alluded to, which injured the rails, may be compared; but if the cutting edges of those shears were rounded, and the surface increased, then the strongest machine that was ever yet constructed for shearing would be unable to effect an incision; in like manner the improved Chairs, with their edges rounded to the curve of the rail, and extended longitudinally (as shown in the drawings) would be unable to cut, but merely hold the rail secure.

The following are the principal advantages of this Chair:—

1st.—The lower head of the rail is preserved free from injury, while the upper one is in use.

2nd.—The abutment-piece, or loose jaw, forms a self-acting fastening.

3rd.—The Improved Chair gives the rail great additional stiffness, vertically and laterally.

4th.—The length of the jaws of the Chairs causes the distance of unsupported rail between Chairs placed the usual distance apart to be less than with those in ordinary use.

5th.—This Chair, by preventing the ends of the rails lipping, and securing level joints, lessens the wear and tear of the rolling stock, and promotes ease in travelling.

6th.—The keys require much less attention, as their office is not to support the rail, as in the common Chair, but only to keep it from rising in the Chair.

7th.—The above advantages are secured at a very slight extra expense on the first cost of the chair.

In conclusion it may be stated, that the Engineers who have adopted the improved Chair, admit that the advantages here enumerated are so far fully borne out in practice.

The following experiments were made with Mr. Marshall on these chairs :—

First Experiment.

The rail experimented upon was the same section as used on the Liverpool, Crosby, and Southport Railway, viz., 5 inches deep and 2½ inches broad in the head, by ⅝ inch thick in the web, and 72lbs. per yard. One of these rails being placed in one of the improved Chairs, as shown in Fig. 9, Plate 2, downward pressure was applied by the hydraulic ram H, at the points A B, until the end of the abutment-piece in the Chair cracked at C, through the deflection of the rail; the rail being taken out, the permanent deflection was ⅝ of an inch in the 3 feet between the centre of the supports A and B. The pressure when the end of the abutment-piece cracked was nearly 40 tons. While the rail was deflecting the motion of the scale upon the surface of the rail was very conspicuous. The amount of deflection of the rail was the entire cause of the fracture of the abutment-piece.

Second Experiment.

The pressure was applied on a joint Chair, and two intermediate Chairs, as shown in Fig. 10. The same experiment was then tried with common Chairs instead of the improved Chairs, a line being drawn across in each case to gauge the deflection at D and E.

The results are shown in the following table :—

TABLE OF EXPERIMENTS ON DEFLECTION OF RAIL.

Pressure.	Deflection with Improved Chair.	Deflection with Ordinary Chair.
Tons.	Inches.	Inches.
15	—	—
20	—	—
31	·01 (about)	·02 (about)
40	·07	·12
50	·12	·16
60	·14	·19
70	·16	·25

At 40 tons pressure one of the outside Chairs broke across the sole, but another being substituted for it, the experiment proceeded

without interruption, the result obtained being as stated above. The lateral deflection in each case was as shown in Fig. 12, when examined after the experiment, being one-half less with the improved than with the ordinary Chairs. These results were unexpectedly satisfactory, proving the superiority of the new Chair over those in common use, by its adding to the stiffness of the rail, and increasing its capability to sustain weight. This may be accounted for by the improved Chair holding the rails much tighter than the common Chair; the side pressure of the abutment-pieces having the effect of tightening the rails in their Chairs in proportion to the pressure applied, but with the common Chair the effect of the pressure being to loosen the rails in the Chairs.

It is a well-known fact with respect to girders, that if two are made precisely alike in all particulars, and fixed in a building, the one with its ends made tight in the walls, while the ends of the other are left loose, merely resting on the wall, then if the latter one is weighted till it breaks, the same weights may be placed on the former one with impunity, without any fracture taking place. From a similar reason the new Chairs add to the stiffness of the rails, and preserve them from deflecting *laterally* and vertically to the extent they do in the common Chairs. The object of the next and last experiment was to test the strength of the Chair. The rail was put in an intermediate Chair, and the pressure applied, as shown in the sketch, Fig. 11. When the pressure reached 60 tons, the rail broke through in the centre of the Chair, cracking off simultaneously the ends of the wedge, but without any other injury to the Chair.

Mr. McConochie exhibited to the meeting specimens of the Improved Chair, and the Chair that was tested in the experiment last described, with the rail in it, showing the fracture that took place.

Mr. McConnell inquired what angle had been adopted for the inclination of the wedge-piece in the Chair?

Mr. McConochie replied, that from their experience an angle of 45° was considered the best, to distribute the strain most uniformly, vertically and horizontally; they had tried a more acute angle at first,

and tested the strength of the chair by a heavy weight falling upon it, until it was broken.

The CHAIRMAN inquired how the Chairs had been found to stand where they had been laid down in regular use?

Mr. McCONOCHIE replied, that three or four miles of one line were laid with these Chairs on the Liverpool, Crosby, and Southport Railway, part of which had been laid five months; a few hundred yards had also been laid with them, for about three months, at the entrance to the Liverpool Station of the Lancashire and Yorkshire Railway, where there was a large traffic constantly working over them with heavy engines; the road was found to keep in better order with the Improved Chairs than with the ordinary ones, and was smoother to run upon, and nothing had been done to the Chairs since they were first laid down.

The CHAIRMAN observed, that he remembered the circumstance alluded to in the paper of the Chairs tried on the London and Birmingham Railway, but he had no recollection of the head of the rail being injured, the Chairs had the effect of splitting the ends of the rails; his impression was, that the rail was entirely suspended, not resting on the bottom, and the object was to steady the rail in the Chair. The fracture took place in the centre of the web, spreading three or four inches lengthways into the end of the rail; he then came to the conclusion that the best support for any girder is at the bottom of the underside, where the strain is simply compression of the material.

Mr. McCONOCHIE said he had tried the effect of reducing the thickness of the web of the rail at the ends, by planing off a portion on each side of some that were laid down, in order to test this point experimentally, but no signs of splitting were yet perceived; though, of course, such a tendency might not show itself for a considerable time.

Mr. McCONNELL remarked, that the rail being gripped as in a vice, by resting between the two inclined surfaces, there would only be compression upon the metal, not any force tending to draw and tear it asunder vertically.

The CHAIRMAN doubted whether any such grip of the Chair could be considered practically to hold the rail under the hammering and clattering action of heavy engines running over it at speed.

Mr. FOTHERGILL observed, that with the sinking of the sleeper the key would throw a cross strain upon the end of the rail, tending to

split it, from the length of leverage given by the grip of the Chair upon the key and rail.

The Chairman remarked, that there would certainly be that strain, though it might be a question whether the actual amount of it was sufficient to cause an injurious effect. A long time was required before the effect on the rails was apparent in those alluded to on the London and Birmingham Railway; it was perhaps 1½ years before it became an extensive defect.

Mr. McConnell inquired whether the Chairs were cast chilled?

Mr. McConochie replied, they were sand castings; they were found sufficiently accurate without being chilled.

Mr. E. A. Cowper asked whether any difficulty was found in getting a fair bearing for the rail on each side, by casting the Chairs so that the two jaws should be an equal height?

Mr. McConochie answered, that it was found quite sufficient to leave the casting rather proud in the shoulder, so as to bear first in the neck of the rail, that the pressure might not come too much on the outer edges of the chair and wedge.

Mr. E. A. Cowper thought the deflection at the joint would cause a tendency to split the rail end, and that fishing-pieces would be better, as they would throw a less proportion of strain upon the rail; a combination of the two, namely, fishing-pieces at the joint, with these Chairs as intermediate chairs, would make a nearly perfect road.

The Chairman observed, that the same objection of the strain applied also to the fishing-pieces, though in a somewhat less degree. He inquired whether the weight of the new Chair was not rather more than that of common Chairs?

Mr. McConochie replied, that they were about the same weight; the new Chairs were about 28 lbs., and the common ones 25 lbs., on the Liverpool, Crosby, and Southport Railway. There was less deflection than with the ordinary Chairs, nor was there any injurious strain perceptible; no failure of the Chairs had occurred, on the contrary, the Engineer of the Line wanted to reduce the weight of the Chairs to the 25 lbs. in future, though he (Mr. McConochie) did not recommend any diminution in their weight.

The Chairman said he would rather advise that the Chairs should be made heavier, than any reduction in the weight; the main source of

durability in the permanent way was the absolute weight of material, and he thought it a great mistake to attempt a reduction of the weight.

Mr. McConochie observed, that he had been struck with the great importance of steadiness of road to ensure the efficient working of locomotives; the steadiest engine was made unsteady by an imperfect road.

Mr. R. Williams said he had seen and travelled over the part of the Liverpool and Southport Railway where these Chairs were laid down, and there was a remarkable difference in the steadiness of that part of the road in comparison with the opposite line, which was laid on common Chairs. It was an unfavourable situation, as the ballasting of the road was very light and loose, and the engines used were of the heaviest class, having, he believed, 13 tons on the driving wheels.

Mr. S. Lloyd, jun., remarked, that as some rails on the Liverpool, Crosby, and Southport Line had been laid down with these Chairs for five or six months, in which the web of the rail was only ½ inch thick, and as the opening pressure of the Chairs on these rails had not been found to do them any injury, he did not see that these Chairs could prove at all injurious where the common sections of rail were used, as in these the thickness of the web varied from ¾ to 1 inch.

Mr. McConochie stated that his object in reducing the thickness of the web in the rails had not been so much to show that the Improved Chair would answer with a lighter section of rail, as to construct a rail which, while no heavier than the ordinary rails, had a greater amount of available wearing surface. The metal taken out of the web, he transferred to the heads of the rail.

Mr. McConnell thought that Mr. McConochie was quite right in this, it being of the first importance to obtain the greatest amount of wear out of a given amount of material; a point requiring much attention in railways. The Improved Railway Chair appeared plainly a step in this direction.

The Chairman said they would be very glad to have a report at a future time on the further results of experience in working the Improved Chair; and proposed a vote of thanks to Mr. McConochie for his Paper, which was passed.

The following Paper, by Mr. J. D. Morries Stirling, was then read :—

ON IRON, AND SOME IMPROVEMENTS IN ITS MANUFACTURE.

The following remarks will but slightly touch on the ores, chemical composition, and general manufacture of Iron; these subjects being greatly too important to be treated of in a communication like the present, and requiring much more research and time than the writer can at present devote, even did he feel himself qualified to undertake the task.

It is most desirable that these subjects should be thoroughly studied, as we are certainly more ignorant of the nature and qualities of iron, and of the differences produced by slight modifications in the mode of manufacture, by varieties of fuel, ores, fluxes, &c., than we are of the nature of any other article of manufacture, and it is to be regretted that in a district like this, where iron manufacture is all-important, so little has as yet been done to elucidate the theory and to improve (on scientific and unerring grounds) the general make of iron, which the writer believes is only to be accomplished by our becoming thoroughly acquainted, as well with the chemical constituents of the various ores, fluxes, &c., as with the changes which these undergo in the various processes of calcining, smelting, refining and puddling. To do this is probably not in the power of those actively engaged in the making of iron, as their other pursuits would materially interfere with the carrying out the necessarily long series of experiments which would be requisite; and, even could such time be devoted to the pursuit, then we should only have, in all probability, the results of trials made in one district.

There is no doubt that many most valuable improvements have been introduced (more especially of late years) by ironmasters and others connected with the iron trade, but these have chiefly had reference to the later stages and finishing processes in iron making, and to the machinery connected with these processes. Of the chemistry of the blast-furnace, of the changes produced by the process of refining, and in puddling, we are still ignorant.

Having devoted a good deal of time to this subject, the writer may be allowed to say, that the more he has studied it, and the more he has seen of iron making, the more convinced he is of our ignorance, and it is to be hoped that some steps will be taken to improve our knowledge and render the various processes certain and economical.

The improvements in iron-manufacture which are touched on in the following remarks, are not of the nature of those alluded to above; they are of an inferior class, and should properly be called improvements in iron, or in the manufacture of certain kinds of iron for certain purposes.

It will be unnecessary to enter minutely into the various processes for converting the iron ore into cast and malleable iron, or to describe at length the various materials used.

The chief varieties of iron ore which are used in this country are the Clay-band, the Black-band, and the Hematite. From the Hematite the purest pig-iron and strongest bar-iron are said to be made; and from Clay-band a stronger malleable iron is generally supposed to be obtained than from the Black-band, but the various qualities can be altered by the judicious ironmaster, and malleable iron of as good quality can be produced from Black-band as from the Hematite or Clay-band. The writer does not here allude to improvement of quality by mixing different ores (by which it is well known the bad qualities of some descriptions are entirely removed), but to the skilful treatment of one or more ores of a somewhat similar character.

The first stage in the manufacture of iron is the conversion of the ore into cast-iron, which is accomplished in various ways. In Great Britain, the ore, after being calcined, if necessary, is introduced with layers of coal or coke, and a flux (usually a carbonate of lime), into a large furnace, and a strong blast (either hot or cold) is urged through the previously kindled mass, to accelerate the combustion of the fuel, and the conversion and fusion of the metal, which is usually tapped from the furnace once in the twelve hours, and run into pigs or ingots, which go by the name of "hot or cold-blast iron," according to the nature of the blast employed. The

subdivisions of both these sorts of iron are the same, viz., Nos. 1, 2, and 3, when for foundry purposes, and forge or white iron when intended for being converted into malleable iron; these numbers and qualities of iron are supposed to differ from each other in the quantity of carbon contained in each, although this is doubted by many eminent chemists. No. 1 is certainly darker, softer, and more carbonaceous-looking than the other numbers, and forge or white iron appears to contain very much less carbon than any iron intended for foundry purposes: but, as we see a similar effect produced on foundry iron by rapid chilling to that produced in forge iron by the supposed abstraction of carbon, it will perhaps be more readily admitted that colour is not a test (or at least not a certain one) of the quantity of carbon which iron contains.

It may be here remarked, that the Nos. 1, 2, 3, give *no real idea* of the nature of the iron; they are relatively comparative, and only indicate the *differences between cast-iron of the same district and make;* thus, what is called No. 1 in Wales, resembles hard No. 2 in Scotland, and corresponds to Staffordshire No. 2 (average); Welsh No. 2 is fully as hard as Staffordshire No. 3, or Scotch No. 4, (a brand), intermediate between No. 3 and forge iron. As a general rule, Nos. 1 and 2 are adapted for small castings, Nos. 2 and 3 *mixed*, for medium castings, and No. 3, or 3 and 4 in Scotland, or 3 in England, for heavy castings; but the mixtures of Welsh and Scotch, or of Staffordshire, Welsh, and Scotch, are found to make stronger and better castings than those made from one sort of iron.

This mode of producing strong castings has been long practised, and is in many places convenient; and the increase of strength is no doubt satisfactory, but there is still a want of uniformity in result, and an occasional difficulty in keeping to the proportions, and even in obtaining the brands specified by the engineer or architect, or chosen by the founder on his own experience.

It seemed to the writer very desirable therefore to obtain, if possible, a kind of iron which should be either uniform and constant in its strength, or, at least, *not under a certain standard*, and, after numerous experiments and trials, he attained this object by making certain mixtures of cast and wrought iron, which have been called "Toughened Cast-iron."

Allusion has already been made to the different numbers of cast-iron, and to their qualities; and it ought further to be stated, that No. 1 is considered the weakest, and No. 3 the strongest. To render these uniform in strength, and at the same time to equalise *that of cast-iron from different districts*, it is only necessary to vary the quantity of wrought-iron introduced, by which means all other mixture is avoided, and so much greater strength insured, as to allow a margin for considerable variation in strength, from any accidental defect, as well as for a diminution in weight, taking the averages of the toughened cast-iron and of the best mixtures.

*Transverse strength of bars, 1 inch square, 4 feet 6 inches between supports.**

Cast-iron, average breaking weight...	436 lbs.
Toughened cast-iron, ditto	733 ,,

*Tensile strength.**

Cast-iron, average breaking weight	7·036 tons.
Toughened cast-iron, ditto	11·790 ,,

Crushing strength.

Cast-iron, average crushing weight	38·582 tons.
Toughened cast-iron, ditto	59·522 ,,

To render the above more intelligible, the proportions are given below, which have been found to bring very soft Scotch (No. 1 hot-blast), and very hard Welsh (No. 2 cold-blast), to nearly the same strength.

Scotch, No. 1 hot-blast, breaking when unmixed at	430 lbs.
With a mixture of 33 per cent. of wrought-iron scrap, broke at	713 lbs.
The same Scotch iron as the first, with only 20 per cent. of malleable scrap, broke at about	620 lbs.
Showing a deficiency in the quantity of the scrap.	
Welsh, No. 2 cold-blast, breaking when unmixed at	440 lbs.
With a mixture of 10 per cent. of wrought-iron scrap, broke at	689 lbs.

* The averages of the transverse and tensile strengths are from the experiments of Mr. Hodgkinson, in the Government Report and elsewhere, and other experimenters; Mr. Hodgkinson is the sole authority for the resistance of crushing force.

The results obtained by Mr. Hodgkinson are very favourable, as shown in the following table, where the breaking weights of common cast-iron and toughened cast-iron are given, from the Report of the Commissioners appointed to inquire into the strength of iron.

Table of Comparative Strength of Cast Iron.

Description of Iron Bars, all two inches square.	Transverse Breaking Load, in Centre.	Tensile Breaking Strength.	Crushing Strength.
	lbs.	Tons per inch.	Tons per inch.
Toughened Cast Iron, with 20 per cent. wrought scrap	2174	11·50	54·64
Low Moor, No. 1	1207	5·67	27·00
Blaenavon, No. 2	1220	7·46	49·11 30·50
Warrington best Gun Mixture ..	1375	—	—

Comparative trials on a larger scale, made by Mr. Owen (by command of the Admiralty), give equally satisfactory results, as the drawings, Figs. 1, 2, 3, 4, Plate 4, show (Compare 1 with 3, and 2 with 4). Tensile strength, according to Mr. Owen, 12·50 tons.

Since these experiments and trials were made, the toughened cast-iron has been successfully used in the construction of several public works, Windsor Bridges, Chelsea Bridge, Yarmouth Bridge, &c., &c.; and it may be mentioned that by being allowed to reduce the scantling in proportion to the increased strength gained by employing the toughened cast-iron, the contractors for the heavy castings of the Manchester Viaduct were enabled *profitably to fulfil* their contract, whereas had they used common iron, and been confined to the specification, they would have been heavy losers.

For shafting, rolls, pinions, cog-wheels, cast-iron railway-carriage wheels, cylinders, and other castings where strength and closeness of texture are desirable, the toughened cast-iron will be found most useful; also, cast-iron which will not chill in its unmixed state, readily chills with less loss of strength than usual, when mixed in proper proportions with malleable iron.

To ensure that the proper proportion of malleable iron is contained in each pig, and also to render the mixture more easily con-

veyed from place to place, the writer prefers making the mixture at the blast-furnace, and this is done by distributing the proper weight of malleable scrap in the moulds into which the melted iron is to be run. It is thus firmly fixed, and melts more easily and regularly with the cast-iron in the cupola or other furnace; the cast and wrought iron heating gradually to the melting point of the former, when the wrought-iron is easily acted upon, and fluxed by the cast-iron.

The process of converting cast into malleable iron is much more varied than that of converting the ore into cast-iron. In some districts a great portion of the cast-iron is refined previous to its conversion; in others little refined iron is used, and in some works cast-iron is at once converted into malleable iron; and this latter process seems to be gaining ground.

Refining is perhaps the least understood, and the least capable of being explained, of any process connected with iron-manufacture. The iron is kept in a fluid state in contact with carbonaceous matter exposed to a blast, and although it would seem that by such means more carbon *ought to be combined* with the iron, experience shows that a great change is produced in the nature of the metal, and that, as far as we know, the *quantity* of carbon is *diminished*, and the iron rendered more nearly akin to malleable iron, or at least so altered as to be more quickly converted into it.

Refining is an expensive process, great waste of material being unavoidable, but it is still necessary for certain descriptions of iron, and the expense is partly compensated by the greater quickness with which the conversion takes place in the puddling furnace.

Puddling is the last and most important process in the conversion of cast into malleable iron. It is still an extremely rude one, and its theory is not understood; it consists in melting in a peculiarly-constructed air furnace, refined or cast iron, or a mixture of them, and as soon as the fusion is complete, in continually stirring the melted metal till spicular or granular particles show themselves. Previous to this the melted metal swells up, and what is technically called boils; gas is evolved, and this appears to be the period at

which conversion commences: the solid particles increase in quantity, and the whole mass acquires a semi-solidity; the workman keeps collecting the more solid portions and forming them into balls, which become larger and larger, until the whole of the malleable iron is collected, and nothing remains but what is called cinder, in a perfectly fluid state, which is afterwards removed from the furnace by tapping, and again used in certain proportions along with ore in reproducing cast-iron. On the removal of this cinder from the iron, by puddling, squeezing, and rolling, the quality of the resulting wrought-iron very much depends.

To avoid the process of refining, to shorten the process of puddling, and to improve the quality of the resulting wrought-iron, are undoubtedly most desirable. The writer has endeavoured to accomplish this, and has reason to believe that partial success has attended his efforts. Instead of using refined iron, a mixture of wrought and cast-iron (as already described) is taken, and after being melted and run into pigs or slabs of the requisite size, it is puddled in the usual way, and the process of puddling is found to be thus so shortened, as to allow of from one to two heats more being brought out in the course of the twelve hours; the yield is greater, and the quality of the iron is much improved as regards fibrousness and tensile strength, rendering such iron particularly well adapted for cable iron, tension bars, shaftings, axles, &c., but not for the wearing surfaces of rails, nor for the tires of wheels.

Before proceeding to touch on certain other processes which the writer believes to improve iron for special purposes, it may be well to point to some alloys of cast-iron, as the making these led him to make the addition of the same and other metals to wrought-iron.

The first is an alloy of iron and tin, which is extremely hard, sonorous, and capable of receiving a very high polish; the addition of manganese, and a very small per-centage of zinc, gives somewhat greater tenacity. Bells made of these alloys have a pure and clear tone. Cast-iron will take up from 20 to 25 per cent. of tin.

Cast-iron alloyed with zinc becomes closer in its texture, and, as far as the writer's experiments have yet gone, stronger, and not less

malleable. Alloys of bismuth, antimony, copper, and silver, possess some scientific interest, but it would be out of place to touch on them now.

Having observed the hardening effect which tin produces upon cast-iron, the writer tried a similar mixture in the puddling furnace, and found a corresponding result, with this essential difference,—that whereas cast-iron will take up about a fifth of its weight, wrought-iron is rendered too hard for subsequent working by any quantity exceeding one per cent.; and taking the various descriptions of iron (Staffordshire, Scotch, and Welsh), one-half per cent. of tin produces a description of iron crystalline, close in texture, and harder than common wrought-iron.

This quality of iron appeared to be suitable for the wearing surfaces of rails, and tires of wheels, and subsequent trials which have been made have fully confirmed this opinion. Lamination is prevented, and the rail, when properly made, wears smoothly and evenly. As in all iron, and particularly in rails, much depends on manufacture; but points and crossings made of this hardened iron, and rails upon sharp inclines, where the wear previously had been very rapid, have been found to last more than double the time of any rails previously tried, and as they are yet not worn out, it is at present impossible to say how much longer they will last. The writer does not believe their increased duration to arise solely from the *greater hardness*, but more from the peculiar crystalline texture and fine grain of the iron resisting the lamination, which great speeds and heavy engines so rapidly produce. The sections of the rails in Figs. 15, 16, 17, Plate 3, show the proportion which it is considered best that the crystalline should bear to the fibrous iron, or to whatever other iron the rail may be composed of.

The addition of zinc, its oxides and other ores, produce the very opposite effect to tin, and the other metals above named. Iron of what is called cold-short quality, is rendered by this means, fibrous tough and strong; red-short iron is also improved in quality by the same means, but it is found that a larger addition of zinc or its ores or oxides is required to effect an improvement in red-short, than in cold-short iron. The quantity necessary to improve cold-

short iron varies much in different districts, and each peculiar iron requires to be separately considered; it is also necessary to know the per-centage of zinc in the ore, if ore be employed, and to ascertain that such ore does not contain foreign matters, which might counteract the effect of the zinc. The addition of these metals to the iron is best made when the iron in the puddling furnace is beginning to boil.

The writer was much gratified to observe in the American Department of the Great Exhibition, a confirmation of his experiments on this subject. Iron, naturally cold-short and red-short, being rendered free from each of these qualities by the addition of an ore of zinc; samples in all stages of progress were exhibited.

Table of Comparative Strength of Wrought Iron.

Description of Iron.	Tensile Breaking Strain.	Deflection with Strain of 9½ cwt.	Permanent Set, in lengths of 2¼ feet.	Final Stretch in length of 2 feet.
	Tons per in.	Inches.	Inches.	Inches.
Hardened Wrought Iron, with ⅔-rds per cent. Tin.	22·92	1·42	1·02	¼
Toughened Wrought Iron ..	27·81	—	—	—
Dundyvan Best Bar	24·33	2·02	1·60	3½
S. C. Crown average result ..	24·47	—	—	—
Hartley's general average of Bar Iron	23·33	—	—	—

Had the limits of a mere sketch like this permitted, the writer would have entered on the consideration of the relative qualities of cold and hot blast iron, and of the effects produced by the use of cinder; also, on some combinations of iron with the earthy bases, and on the effects of various salts and fluxes in the blast and other furnaces. Several other alloys of iron possess considerable interest, and in conclusion, allusion may be made to a remarkable property which iron possesses of closing the grain of other metals and alloys to which it is added in minute quantity.

Mr. Stirling exhibited a number of specimens of the toughened wrought-iron in bars, and the hardened wrought-iron, as applied to the surface of rails, showing their fractures, and specimens of the toughened cast-iron, showing the mode of mixing the wrought-iron scrap with the pig-metal; also specimens of an alloy of zinc copper and tin, and another of the same composition, with an addition of 1½ per cent. of iron, showing the great closeness and fineness of grain that were produced by this small admixture of iron. It was explained that it was advisable to alloy the iron with the zinc before mixing with the copper, otherwise there would be imperfection and unsoundness in the metal, the iron appearing in the form of what are technically called "tears."

The Chairman said he considered it a very important subject, and thought the paper showed valuable results of extensive practical trials combined with scientific inquiry. He asked at what period the tin or zinc was added to the wrought iron?

Mr. Stirling replied, that it was put into the puddling furnace when the extreme of the boiling was just passed, or passing, and conversion just commencing, and the formation of spicula beginning. A more fluid iron required the metal to be put in at a later period, and iron that came to nature sooner required the metal put in earlier. It was difficult to give a definite rule, it could only be judged of by particular experience.

Mr. Duclos thought the presence of zinc in the iron was doubtful; from its volatility, the greater proportion would probably be dissipated in the furnace. He considered it more probable that the change in the iron was caused by the physical quality of the iron undergoing some alteration in consequence of the presence of the zinc.

Mr. Stirling said he did not consider the mixture of zinc with the iron to be in all cases an alloy, as the proportion was occasionally only ¼-th per cent., and he felt uncertain about its mode of action; the quantity of zinc required varied very much, it had to be determined by experiment with the different ores and furnaces.

Mr. Duclos observed, that in some iron works he had been acquainted with in Belgium, he had never found any trace of zinc in the iron made from ore containing zinc, but metallic zinc was found to accumulate in the top of the furnace. Many years since a series of experiments had been made by M. Carsen, on various mixtures of iron with zinc and other metals, but they had not led to any practical appli-

cation. There was no question that sufficient attention had not been paid to the properties of the alloys that can be made with iron, and he was glad to see the steps taken by Mr. Stirling; he did not quite agree as to the want of knowledge of the iron manufacture, he thought there was a great deal of knowledge on the subject, but he would wish the principles carried out further.

Mr. STIRLING remarked, that in the case mentioned, in Belgium, two processes, smelting and refining, intervened, by which most if not all the zinc might be volatilized. There was no doubt that the practical making of iron was well understood, but not the theory and principles, otherwise the processes might be further simplified, and, as the result, iron would most probably be produced complete at one process, instead of two or more. He thought that further improvements would be more studied and accomplished when iron and coal were dearer.

Mr. McCONNELL said there was great room for improvement in railway tires and rails. If the tire now lasted 70,000 miles on the driving wheel of an engine, it was considered very good work. The expense of replacing tires, and of failure, was a very sérious item; and if, by Mr. Stirling's process, the iron could be made to last longer, it would be a great source of economy and convenience.

Mr. BEASLEY inquired why the wrought-iron scrap was put into the pig mould, in making the toughened cast-iron?

Mr. STIRLING replied, that one object was to ensure a definite proportion for each charge: also, the wrought-iron melted more easily in the furnace, when mixed in that manner with the cast-iron, which seemed to act as a flux, the whole getting heated together; the cast-iron dropping, eats away the wrought-iron. If thrown separately into the cupola, part of the cast-iron would melt down first, and the two would not get uniformly mixed; the wrought-iron was liable to get oxidised, and wasted.

Mr. BEASLEY observed, that he was aware if the wrought-iron was thrown into the puddling furnace with the pig, it would burn away and not improve the quality; but if it was thrown into the fire a little time before the puddler commenced balling his iron, it would very much improve the quality.

Mr. STIRLING said that it was an old practice to add wrought-iron in the puddling furnace, in order to get a quicker yield; but it would

not melt thoroughly in that case, and make a uniform mixture. It should be first re-melted in the cupola from the mixed pig, to make a uniform mixture, and then re-melted, and worked in a puddling furnace.

Mr. Beasley remarked, that he had melted wrought-iron in the cupola, and then worked it in the puddling furnace, and he had found the result to be better than from the ordinary pig-iron alone, but it was not a sufficient advantage to make it worth the extra expense; he had obtained a greater yield.

Mr. Stirling observed there was a process for melting wrought-iron, which was then converted back by decarbonising, to a state approaching to steel; it was intended to be used for small articles, such as snuffers, scissors, &c., instead of forging them.

Mr. Adams inquired about the application of the hardened iron to tires; the best scrap tires were found the worst to wear; they laminated more, and consequently he did not use them. Those he used were made he believed of two blooms, the lower one of scrap or other tough iron, and the upper one from a puddled ball not piled; the wearing surface was consequently crystalline iron, hard, not laminated, and was more suitable to resist the rolling and crushing action that the wearing surface of the tire was subjected to.

Mr. Stirling replied, that he had seen a similar process extensively carried on; the lower part of the tire was made of No. 3 iron, and the wearing surface of No. 2 iron, consisting of two puddled balls hammered thoroughly, then re-heated and passed through rolls, and lastly welded to the No. 3 iron for the lower part. For such purposes as the wearing surfaces of wheel tires and rails, scrap iron was certainly the worst, from the inequality of the pieces united by weldings, necessarily numerous and irregular; when the wearing and rolling action came into effect, unequal wear and lamination of the surface must be the result.

Mr. T. Fairbairn said the results of the trials he had made of the toughened cast-iron were a near approximation to Mr. Hodgkinson's experiments; but he did not think it would be prudent, or altogether safe for an architect or engineer to reduce the section of a girder to the extent which the relative transverse strength given in the tables would appear to warrant; he would rather retain the large section, and avail himself of the additional security which the use of the toughened iron undoubtedly gave.

Mr. STIRLING observed, that to obtain the full increase of strength would require different trials with different iron, in order to ascertain the best proportion of scrap; but in the right proportions from the general results of observations, he believed it might be confidently stated, that one fifth of the weight might be taken from ordinary sections of girders, by using the toughened cast-iron, leaving a greater strength of girder; however, he would much prefer seeing all the strength of the ordinary section left for extra safety. The strengths given in the tables in the paper were chiefly taken from Mr. Hodgkinson, and were the average results of his experiments, showing an increase of transverse strength of 78 per cent.

Mr. R. WILLIAMS asked whether in practice any difficulty was found to arise in uniting the two qualities of hard and soft wrought-iron?

Mr. STIRLING replied, that no difficulty was found in the manufacture, and they were found to be soundly welded together.

Mr. R. WILLIAMS observed, that as the hard iron, which melted at a lower temperature than the soft iron, was necessarily the topmost in the pile when placed in the furnace to be welded, either that would be over-heated at the expense of its quality, or the inner piles would be under-heated, and endanger the soundness of the bloom. With regard to the lamination of tires, this was not so much owing to the fact of their being made of piled iron, as to the mode of piling; and by piling the bars edgeways instead of flatways, there was little, if any, liability to laminate. Puddled iron could be made hard or soft, at pleasure, according to the management of the process, without the introduction of any alloy into the puddling furnace.

MR. STIRLING replied, that the hard iron came quite as soon to a welding heat as the other iron, and a most perfect weld resulted.

Mr. McCONNELL remarked, that in the manufacture of steel tires. the steel did not lengthen so much as the iron in rolling, and it made a difficulty in rolling the tires to make them sound throughout; and he inquired whether any difficulty of that kind was found with the hardened iron for the wearing surface of tires and wheels?

Mr. STIRLING replied, that in rails no separation between the materials had been found; he had not yet had experience in tires. On the Edinburgh and Glasgow Railway, on the steep incline, at Cowlairs, Mr. Adie had had rails hardened on this plan laid down for

some years, and had found them to last better than steel-covered rails, which had been also tried, and usually wore out in a considerably shorter time; the hardened rails were still going on well, and an additional portion of that line was now being laid with them. In consequence of the first rails manufactured being made too hard, they showed distinctly a tendency to separate, and the failure was valuable as experience; also they were made more liable to separate by the hardened piece laid on being round-topped in the pile; 50 or 60 rails made at the very first works where the plan had been tried, had been broken at different times for examination, and were found quite sound.

Mr. E. A. Cowper said he had used wrought-iron scrap mixed with cast-iron in the ladle, the metal being taken rather hotter than usual; it closed the grain of the iron very much, and was found advantageous in casting hydraulic presses, or other castings where a very close grain was required. He had put in as much as 15 per cent. of scrap.

Mr. Stirling observed, that he had never found that more than about 5 per cent. could be combined in that manner, and then the mixture must be more or less imperfect, and the metal would be partially chilled.

Mr. Cowper said he had not found any objection from the metal being cooled; it was taken pretty hot, and clean iron turnings were put into the ladle, and well stirred up, which secured complete mixture and fusion.

Mr. Slaughter inquired what was the relative cost of toughened cast-iron?

Mr. Stirling replied, that in a girder, if the section were reduced one-fifth, the cost would be cheaper; if the price of cast-iron were very low, the toughened iron would then be proportionately dearer.

Mr. Slaughter said he had tried the toughened iron for a number of locomotive cylinders, at the recommendation of Mr. Gooch, on the Great Western Railway, and found it made very fine, perfect, and sound castings, better than he had ever made before. He intended to continue the use of it, and considered it an excellent material for cylinder castings, and preferable for any purpose for which the strongest and best iron was required. He did not find the iron dearer, but on the contrary, less expensive than the iron he had previously used for the purpose.

Mr. STIRLING explained that the toughened iron might be made from a cheaper iron, such as the Scotch hot-blast, which at £3 per ton would be about £3 10s. for the cost of the toughened iron, which would then surpass in strength a dearer iron, such as Blaenavon at £5 or £5 10s. per ton; so that although the increased expense of the process was 10s. or 12s. per ton, the final cost was less, because a cheaper description of iron could be used, and a greater strength was at the same time obtained, as shown in the table of experiments.

Mr. SLAUGHTER said he had found that the toughened iron was less expensive. That which he used was made from Dundyvan or Calder iron, at £3 or £3 10s. per ton, and he found it better, when toughened, than the cold-blast iron which he had previously used at £5 or £5 10s. per ton.

The CHAIRMAN proposed a vote of thanks to Mr. Stirling, for his valuable and interesting paper, which was passed. He thought that important practical results were likely to follow from such an able investigation, and they were much indebted to Mr. Stirling for bringing it before them, and he trusted that he would continue the course, and favour the Institution with the further results.

The following paper, by Mr. Edward A. Cowper, of London, was then read :—

DESCRIPTION OF CUGNOT'S ORIGINAL INVENTION OF THE LOCOMOTIVE STEAM ENGINE FOR COMMON ROADS.

The object of the present Paper is to put the Members of this Institution in possession of certain information, which was obtained by the writer and your Secretary when in Paris, in reference to a Locomotive Steam Engine for Common Roads, which they saw in the "Conservatoire des Arts et Metiers."

Attention was first drawn to the subject by a model of a locomotive on three wheels, placed in a glass case in the "Conservatoire," and on making diligent inquiries it appeared that the actual engine itself was preserved in an old Church, that had been appropriated for the reception of various kinds of interesting machines, within the bounds of the "Conservatoire."

Permission to view the engine having been obtained, through the kindness of the Officer of the Institution, the engine was examined carefully, and general dimensions were taken, and a most interesting sight it was, to see the actual first machine that man had made to run alone by steam; it was a most creditable piece of work, considering when it was made, and would no doubt have caused a much greater sensation in the world than it did, had it not met with a serious accident after it had had two or three little walks only.

The Officer who showed the engine, explained that as it was passing along a street near where the Madeleine now stands, in turning a corner it overbalanced itself, and fell over with a crash; and, unfortunately, instead of being allowed to get the better of the bruise, and have another trial, it was at once locked up to keep it out of harm.

The following particulars have been translated from the French description, obligingly furnished to the writer by his friend, M. Armengaud, Professor at the "Conservatoire des Arts et Metiers."

The accompanying drawings, Figs. 1, 2, 3, and 4, Plates 5, 6, and 7, have been made by your Secretary from the drawing kindly sent by M. Armengaud.

It appears from documents collected by M. Morin, that a native of Lorraine, in France, named Cugnot, is entitled to the credit of having first constructed a carriage whose wheels were propelled by steam, and that in 1769 he made a locomotive on three wheels, to run on common roads, which was put in motion by a steam engine composed of two single-acting cylinders, whose pistons acted alternately on the single front wheel. Nicholas Joseph Cugnot, whose name has been hitherto overlooked in the history of the locomotive steam engine, was born at Void, in Lorraine, on 26th February, 1729, and died at Paris in 1804.

In the trials of Cugnot's machine, which were made at the Arsenal, in the presence of the Duke de Choiseul then Minister of War, General Gribeauval First Inspector-General of Artillery, and other eminent persons, the new vehicle, loaded with four persons, could not travel faster than 2¼ miles per hour; and the size of the boiler not being sufficient, it would not continue at work

longer than 12 or 15 minutes; it was then necessary to wait until the steam had again risen to a sufficient pressure before it could proceed further.

In 1770, Cugnot constructed a new machine, which gave more satisfactory results; the trials made by order of the Duke de Choiseul were however abandoned. The employment of steam engines in the place of animals to convey merchandise and passengers, could not become a practically successful application without the aid of the iron railways of England; and the difficulty of managing the machine on common roads stopped the invention of locomotive steam engines in France, and the efforts of Cugnot.

Whilst the first machine of Cugnot was in course of construction, in 1769, a Swiss Officer, named Planta, presented to the Duke de Choiseul a similar project; but perceiving that Cugnot's machine was preferable to his own, he did not proceed any further with it.

The following is a description of the machine:—Fig. 1, Plate 5, is a side elevation; Fig. 2, Plate 6, a plan; Fig. 3, Plate 7, a transverse section; and Fig. 4, a longitudinal section of the front portion.

The machine is composed of two parts; the front one (in place of the horse) being supported by a single driving wheel M; these two parts are united by a moveable pin E, and a toothed sector S, fixed on the framing LL of the front part.

The hind part T is merely a carriage on two wheels RR, intended to convey the load, and furnished in front with a seat B, for the conductor.

The fore part carries the copper boiler C, having a furnace inside, provided with two small chimneys; the two single-acting brass steam cylinders AA communicating with the boiler by the pipe O, and the machinery for communicating the motion of the pistons to the driving wheel M.

When one of the pistons P descends, the piston rod D draws with it the crank F, the catch of which causes the driving-wheel to make a quarter of a revolution by means of the ratchet wheel G, which is fixed on the axle of the driving wheel; at the same time the chain H, fixed to the crank on the same side, descends also, and moves the lever I, the opposite end of which is raised, and restores

the second piston to its original position at the top of the cylinder, by the interposition of a second chain and crank.

The piston-rod of the descending piston, by means of a catch Y, causes the levers Q Q to turn round, moving the levers Z Z at the same time, and the chain fixed to them turns the four-way cock W, and opens the second cylinder to the steam, and the first cylinder to the atmosphere. The second piston then descends in its turn, causing the driving-wheel to make another quarter revolution, and restores the first piston to its original position; and thus the process is repeated.

In order to allow of changing the direction of the motion, and make the vehicle run backwards, the catch of the crank F was arranged in such a manner that it could at pleasure be made to act either above or below; in order to obtain a backward motion it was merely necessary to make it act on the upper side (changing the position of the spring which pressed upon it); then when the piston drove it down, it slipped over the ratchet wheel, and on the other hand the catch on the opposite side was raised by the lever, and turned the wheel a quarter revolution in the direction contrary to the original motion.

The conductor could further turn the carriage at an angle of from 15° to 20°, by means of a set of cog wheels N N, the last of which worked on the toothed sector S, and the first of which was turned by a spindle furnished at the top with a double handle in front of the seat B.

It will no doubt be in the recollection of most of the Members, that the earliest recorded date of any other Locomotive was that of Murdock, in 1784, being 15 years later than Cugnot's engine; this engine was shown at work at a former meeting of this Institution.

Various persons have suggested the moving vehicles by steam, but none it appears so early as Cugnot, who actually ran an engine on land. Papin certainly, in his work published at Capel in 1699, suggested the use of ratchets, to convert the motion of a piston into a circular motion, but it does not appear that he had any idea of a locomotive.

After the date of Cugnot's engine, there are several persons whose names should be mentioned as having suggested the use of steam for locomotion, viz.:—Watt, in 1784; Oliver Evans, in 1786;

Professor Robinson, in 1795; and lastly, Trevithick and Vivian, in 1804, who not only ran a locomotive steam engine, but laid down *rails* for it to run on, at Merthyr Tydvil, in South Wales; and from this time the improvements introduced in locomotives and railways have been almost incessant, until we have now good smooth roads, and locomotives which run much faster than the wind.

The CHAIRMAN observed that the paper was an interesting record of the first attempt to apply steam to locomotion, and it appeared that they had not been hitherto giving the credit where it was really due. It was highly interesting and instructive to look back in tracing the progress of invention, to see how much the ingenuity of man had been directed to do something that was mistaken in its object. Generally the first attempts at invention commenced with a complicated machine, and the progress of subsequent improvements was gradually to simplify, a vast amount of ingenuity having been expended in overcoming difficulties which need not have been encountered.

A vote of thanks to Mr. Cowper for his communication was proposed by the Chairman, and passed.

The following paper, by Mr. Alexander Allan, of Crewe, was then read:—

DESCRIPTION OF AN OIL AXLE-BOX FOR ENGINES AND TENDERS.

An Axle-box for the driving-wheels of passenger engines, is shown in Figs. 1 and 2, Plate 8:—

A is the axle-box, of cast-iron, with two wrought-iron pieces cast in the sides of it.

B, the axle-step, which is carried 1 inch below the centre, to assist the sides in resisting the horizontal thrust; the inside edge W is also carried lower than the outside of the sponge-box, which carries the oil over the joint of axle-step and sponge-box joint.

S, the sponge-box; in it are placed one or two pieces of sponge, a ittle thicker than the distance from axle to bottom of sponge-box.

The axle is 6½ inches in diameter, and is supplied with oil by a covered syphon-box on the top of a straight tube about 3 feet long, and directly over the axle at X, which tube goes 1¼ inches into the axle-box, and allows the engine to rise or fall 1¼ inches, the delivery of oil on the proper place is therefore certain. I I are two pins, ½ inch round iron, to support the sponge-box.

E, the connection with the spring.

F, the pin which connects E with the sides of axle-box.

T, are pieces of wrought-iron cast in the axle-boxes; the lower ends are drilled for the pin F.

Axle-boxes for the leading and trailing wheels of passenger engines, also of tenders similar to those experimented on, are shown in Figs. 3, 4, and 5, Plate 8.

A, a cast-iron axle-box, with strong covered top to support the weight; under there is a cored-out hollow space, open at one end, and into this hollow the brass oil cup C is fitted.

B, the axle-step, 1 inch thick, with 3 snugs to resist the lateral strain, and with two counter-sunk oil holes.

C, the oil cup, with two tubes forming syphons; and H a handle for lifting it out to trim, &c.

S is the sponge-box, into which the narrow slip of sponge is placed, to catch the surplus oil as it leaves the axle bearing.

In accordance with the request at the last meeting of the Institution, the following experiments have been made on the consumption of oil in the axleboxes of tenders alone, fitted with oil receivers and sponges for collecting the oil, as described above; these experiments lasted seven days.

	s.	*d.*	
6·08 quarts of oil used, at 9d. per quart...	4	6¾	
Four sponges at ½d. each	0	2	
For running 6,000 miles...	4	8¾	or ¾d. per day.

N.B.—This result was obtained by running 1972 miles, with three tenders, and reduced to 6000 miles, as a mean of comparison with the axle-box described at the last meeting. The same system has been in operation on the Northern Division of the London and North Western Railway for the last ten or twelve years.

Mr. LEA inquired how many bearings had been tried in Mr. Allan's experiments?

Mr. ALLAN replied that the four bearings of the tender alone were tried; he had checked the experiment by trying it with other men, and found very little variation in the consumption: they had never exceeded one penny per day.

Mr. LEA said he should be glad to try a corresponding experiment with the new lubricating composition that he had mentioned at the last meeting of the Institution, which was quite applicable to that kind of axle-box, and he considered would effect a considerable further economy.

The CHAIRMAN remarked that in any comparative experiments, care should be taken to have the weights on the journals equal.

Mr. LEA said he proposed to try the journals on the opposite sides of the tender or carriage, with the two different lubricating materials at the same time, so as to ensure equality of load and mileage and all circumstances. He had obtained results from several railways of the cost of lubrication, and he hoped to have an opportunity to make further experiments before the next meeting of the Institution.

Mr. FOTHERGILL observed that the diameter and width also of the journals was of much importance in the lubrication; in small machinery, in particular, the size of journals made a great difference.

Mr. McCONNELL remarked that the most economical mode of lubrication was certainly an important subject for experiment on railways, as it was a serious item of expenditure; the two points should be tried separately—the best material for lubrication, and the best mode of applying it.

The CHAIRMAN proposed a vote of thanks to Mr. Allan for his communication, which was passed.

The Meeting then adjourned; and in the evening a number of the members and their friends dined together, in celebration of the Anniversary of the foundation of the Institution.

SUBJECTS FOR PAPERS.

Steam Engine Boilers, particulars of construction—form—heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—steam gauges, high pressure and low pressure—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—incrustation of boilers, and means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working.

Steam Engines, expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—comparative advantages of direct-acting and beam engines—indicator figures from engines, with details of useful effects, consumption of fuel, &c.—contributions of indicator figures for the general book of reference kept in the Institution.

Pumping Engines, particulars of various constructions—size of cylinder and pumps, strokes per minute, and horse-power—number and size of pumps and strokes per minute—comparison of double-acting and single-acting pumping engines—particular details of different valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

Blast Engines, best kind of engine—size of cylinder, strokes per minute, and horse-power—details of boilers—size of blowing cylinder and strokes per minute—pressure and means of regulating the blast—improvements in blast cylinders—rotary blowing machines.

Marine Engines, power of engines in proportion to tonnage—different constructions of engines—dynamical effect compared with indicator figures—comparative economy and durability of different boilers, tubular boilers, flat flue boilers, &c.—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in the form, number of arms, material, means for unshipping, horse-power applied, speed obtained, section of vessel—iron and wood ships, details of construction, lines, tonnage, cost, &c.

Rotary Engines, particulars of construction and practical application—details of the results of working.

Locomotive Engines, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—speed of engines, cost, power, weight, steadiness—consumption of fuel—heating surface, length and diameter of tubes—experiments on size of tubes and blast-pipe—comparative expense of working and repairing—best make of pistons, valve gear, expansion gear, &c.

Caloric Engines, and Engines worked by Gas, Gun-cotton, or other explosive compounds—comparative consumption per horse-power per hour.

Electro-Magnetic Engines, particulars and results.

Water Wheels, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, per-centage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

WIND MILLS, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

CORN MILLS, particulars of improvements—power employed—application of steam power—results of working with an air blast and small stones—advantages of regularity of motion.

SUGAR MILLS, particulars of the construction and working—results of the application of the hydraulic press in place of rolls.

SAW MILLS, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws.

OIL MILLS, facts relating to the construction and working, by stampers and by pressure.

COTTON MILLS, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning and carding machinery, &c.

MACHINERY for manufacturing Flax, both in the natural length of staple and when cut.

ROLLING MILLS, improvements in machinery for making iron and steel—mode of applying power—steam hammers—piling of iron—plates—fancy sections.

STAMPING AND COINING MACHINERY, particulars of improvements, &c.

PAPER-MAKING AND PAPER-CUTTING MACHINES, ditto ditto

PRINTING MACHINES, ditto ditto

CALICO-PRINTING MACHINERY, ditto ditto

WATER PUMPS, facts relating to the best construction, means of working, and application—best forms—velocity of piston—construction of valves.

AIR PUMPS, ditto ditto ditto

HYDRAULIC PRESSES, facts relating to the best construction, means of working, and application.

ROTARY AND CENTRIFUGAL PUMPS, ditto ditto ditto.

FIRE ENGINES, ditto ditto ditto.

SLUICES AND SLUICE COCKS, ditto ditto ditto.

CRANES, ditto ditto ditto.

STEAM CRANES, HYDRAULIC CRANES, PNEUMATIC CRANES, ditto.

LIFTS FOR RAISING TRUCKS, &c. ditto ditto ditto.

LATHES, PLANING, BORING, AND SLOTTING MACHINES, &c., particulars of improvements—description of new self-acting tools.

TOOTHED WHEELS, best construction and form of teeth—results of working—power transmitted.

DRIVING BELTS AND STRAPS, best make and material, leather, rope, wire, gutta percha, &c.—comparative durability, and results of working—power communicated by certain sizes.

DYNAMOMETERS, pressure gauges, indicators, governors, &c., construction and working.

STRENGTH OF MATERIALS—facts relating to experiments on ditto, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—best forms and proportions of girders for different purposes—best mixtures of metal—mixture of wrought iron with cast.

DURABILITY OF TIMBER of various kinds—best plans for seasoning timber and cordage—results of Kyan's, Payne's, Bethell's, and Burnett's processes, &c.—comparative durability of timber in different situations.

CORROSION OF METALS by salt and fresh water, and by the atmosphere, &c—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean.

ALLOYS OF METALS—facts relating to different alloys.

FRICTION OF VARIOUS BODIES—facts relating to friction under ordinary circumstances—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axle-boxes, &c.—lubrication, best materials and means of application, and results of practical trials—best plans for oil tests.

IRON ROOFS, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast-iron, wrought-iron, timber, &c., best construction, form, and material—details of large roofs and cost.

FIRE-PROOF BUILDINGS, particulars of construction—most efficient plan—results of trials.

CHIMNEY STACKS of large size, particulars, mode of building, cheapest construction, &c.

BRICKS, manufacture and durability—hollow bricks, fire-bricks, and fire-clay—perforated bricks, cost of manufacture, and advantages.

GAS WORKS—best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, water gas, &c.—improvements in purifiers, condensers, and gas holders—wet and dry gas meters—pressure of gas, gas exhauster—gas pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

WATER WORKS—facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—relative advantages of stand-pipes and air vessels.

WELL SINKING AND ARTESIAN WELLS, facts relating to.

COFFER DAMS AND PILING, facts relating to the construction.

PIERS, fixed and floating, and Pontoons, ditto ditto.

PILE-DRIVING APPARATUS, particulars of improvements—use of steam power—Pott's apparatus—the compressed air system.

DREDGING MACHINES, particulars of improvements—application of dredging machines—power required, and work done.

DIVING BELLS AND DIVING DRESSES, facts relating to the best construction.

CAST-IRON AND WROUGHT-IRON LIGHTHOUSES, ditto ditto

MINING OPERATIONS, facts relating to mining—means of ventilating mines, use of steam jet and ventilating machinery—mode of raising materials—mode of breaking, pulverising, and sifting various descriptions of ores.

BLASTING, facts relating to blasting under water, and blasting generally—use of gun cotton, &c.—effects produced by large and small charges of powder.

BLAST FURNACES—consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse-power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast.

PUDDLING FURNACES, best forms and construction—worked with coal, charcoal, &c.

HEATING FURNACES, best construction—consumption of fuel, &c.

SMITHS' FORGES, best construction—size and material—power of blast—hot blast, &c.

SMITHS' FANS, and FANS generally, best construction, form of blades, &c., with facts relating to the amount of power employed and the per-centage of effect produced.

COKE AND CHARCOAL, particulars of the best mode of making, and construction of ovens, &c.

RAILWAYS—construction of permanent way—section of rails, and mode of manufacture—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

SWITCHES and CROSSINGS, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

TURNTABLES, particulars of various constructions and improvements.

SIGNALS for Stations and Trains, and self-acting signals.

BREAKS for Carriages and Waggons, best construction.

BUFFERS for Carriages, &c., and Station Buffers—different construction and materials.

SPRINGS for Carriages, &c., buffing and bearing springs—particulars of different constructions and materials, steel, india-rubber, &c.—results of working.

RAILWAY WHEELS, wrought-iron, cast-iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought-iron and steel tires, comparative economy and results of working—solid wrought-iron wheels.

RAILWAY AXLES, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The Council invite communications from the Members and their friends, on the preceeding subjects, and on any Engineering subjects that will be useful and interesting to the Institution;—also presentations of Engineering drawings, models, and books for the library of the Institution.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the communications should be on so large a scale, as to be clearly visible to the meeting at the time of reading the communication, or enlarged diagrams should be sent for the illustration of any particular portions.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET,

For the year ending 31*st December*, 1852.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Balance from 31st December, 1851	202	15	2	By Printing and Engraving Reports of Proceedings.	94	8	0
„ Subscriptions from 18 old Members in arrear.	54	0	0	„ Stationery and Printing	25	7	11
„ ditto from 145 old Members for 1852.	435	0	0	„ Office Expenses and Petty Disbursements	24	7	1
„ ditto from 21 new Members for 1852.	105	0	0	„ Travelling Expenses	8	14	6
„ ditto from 3 old Graduates for 1852	6	0	0	„ Parcels	5	2	7
„ ditto from 1 Member in advance for 1853	3	0	0	„ Postages	27	15	5
„ Sale of Extra Reports.	7	9	1	„ Salary	350	0	0
„ ditto ditto Engravings	3	0	0	„ Rent and Taxes.	107	7	6
				„ Balance 31st December, 1852	173	1	3
	£816	4	3		£816	4	3

(Signed) J. E. CLIFT, J. RAMSBOTTOM, } FINANCE COMMITTEE.

26*th January*, 1853.

PROCEEDINGS.

APRIL 27, 1853.

The GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, April 27th, 1853, ARCHIBALD SLATE, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Ballot-papers were opened, and the following new Members were declared to be duly elected:—

MEMBERS.

GEORGE ADDENBROOKE, Darlaston.
WILLIAM EALES, London.
DAVID JOY, Worcester.
WILLIAM MATHEWS, Birmingham.
GEORGE M. MILLER, Dublin.
JONATHAN ROGERS, Pontypool.
JAMES SOLLY, Tipton.
EDWARD B. WILSON, Leeds.
FRANCIS W. WYMER, Newcastle-on-Tyne.

HONORARY MEMBER.

WILLIAM SUTTON, Birmingham.

The following Paper, by Mr. William G. Craig, of Newport, was then read:—

ON IMPROVED INDIA-RUBBER SPRINGS FOR RAILWAY ENGINES, CARRIAGES, &c.

In order to explain the difficulties which have been contended with and surmounted by the use of these springs, the condition of the roads upon which they have produced such satisfactory results has to be noticed, and the causes which first led to the introduction of India-rubber as a substitute for steel, in bearing springs, buffers, and draw springs.

The Western Valleys Lines of the Monmouthshire Railway and Canal Company, (upon which the writer is Locomotive Superintendent,) consist of twenty-five miles of tramway, exclusive of branches, and worked by heavy coupled engines of the most improved construction. The tramplate is laid by means of chairs upon transverse sleepers, about 3 feet apart, and an intermediate sleeper at the joints. This plate, although heavy, (about 73 lbs. per yard) is of very weak section, as shown by the accompanying drawing, Fig, 4, Plate 9, and there is consequently considerable deflection in it, a tendency to rise at the joints, and for the sleepers to work loose; the effect of this is, to cause a much greater expenditure of power necessary to overcome a series of rising and falling gradients, than would be the case upon an edge rail, and an undulatory motion of the engine is caused, which is extremely destructive to the steel springs hitherto in use on this line. The curves are also unusually sharp, (some being under five chains radius, and the majority under twenty chains,) which is productive of a prejudicial effect on the wheels, buffers, and other parts of the engines, carriages, and waggons. The gradients are very heavy, (some being 1 in 54,) producing a much greater strain on the draw-bars and couplings than is to be met with upon ordinary railways.

Upon such a road, the inconveniences attending the use of steel springs were both numerous and formidable. In addition to the continual repairs which were required by the springs themselves, the injury done to the permanent way, arising from the unequal action of the springs, and the violent concussions they were subject to, when they were totally disabled (as was frequently the case), was large in amount and of continual occurrence, and of a character that involved considerable expense in repairs. Some idea of the damage thus occasioned may be formed from the fact of the wheel tyres requiring to be replaced at least every eight months, having become worn by that time into a series of flats, more nearly resembling an irregular polygon in outline than the circumference of a circle.

Fig. 4 shows a section of the engine tyres used on the tramways: they are steeled on the wearing surface. With regard to the springs themselves, it may be proper to mention here that the item of expenditure for steel springs (including wages for repairing them) was £251 9s. 9d. in six months, for fifteen engines only.

Such then were the circumstances when it was deemed necessary to test the application of India-rubber to the various purposes before mentioned, and the results have been attended with such marked success, as to exceed the most sanguine anticipations entertained.

The India-rubber Springs described in this paper are constructed on Mr. Coleman's plan. Fig. 1, Plate 9, represents the first form of application, for engine-bearing springs. It consists of a cylinder of prepared India-rubber A, 9 inches long and 9 inches in diameter, with a hole through it of 1¾ inch for the spring pin; it is supported by a wrought-iron plate 1⅛ inch thick, which rests on a shoulder on the spring-pin, and is covered by a wrought-iron plate and crossbar, through which pass the spring links attached to the outside framing at the bottom, and secured by set and jam nuts at the upper end. The India-rubber is prevented from undue lateral expansion by two ¾-inch round iron hoops, and from internal compression and friction on the spring pin, by a helical coil of strong wire; instead of this wire, wrought-iron ferrules are now used. To obviate an inconvenience which has been occasionally complained of, in passing over unusually rough portions of the road, viz., the jumping motion of the engines, from the great elasticity of the springs—it was found necessary to insert between the bottom plate and the top of the framing another smaller cylinder of India-rubber B, for the purpose of absorbing the recoil of the spring, and to prevent any motion being re-communicated from the spring to the framing. This had the desired effect, and the engine was found afterwards to run uniformly steady, at all varieties of speed, and however great the inequalities of the road.

Upon engines with inside framing, or where sufficient space for the springs could not be obtained, two cylinders or sometimes three were used, AAA, as in Fig. 2, which represents the springs in use on the engines Nos. 2, 3, 4, and 5.

In the application of the same description of spring to a tender, the India-rubber is 6⅛ inches diameter, 7 inches long, with a 1¾ inch hole, and bears against a cast-iron bracket bolted to the framework of the tender, the bottom plate being supported by a set nut on the spring pin, which passes loosely through a hole in the underside of the bracket, and rests on a wrought-iron plate, ⅝ inch thick, made to fit in the top of the axle-box.

Fig. 3 shows a similar arrangement applied to waggons. In the passenger carriages, two of these springs are used in pairs, in order to obtain a greater amount of elasticity, without increasing the distance between the centre of the axle and the sole bar, and a modified form of axle-box is introduced, to meet the requirements of the double cylinder of India-rubber. No horn plates are used in this case, their place being supplied by two guide rods, which pass through the axle-box and India-rubber cylinders, being firmly bolted to the sole bar by jaws on the upper ends, and kept in their places by diagonal stays at the lower ends. The axle-box is cast with a projecting hollow wing on each side, which is enlarged on the top, to afford a bearing for the bottom of the India-rubber cylinder, and leaving a capacious grease-box between them. The upper ends of the India-rubber cylinders are received into a cast-iron plate, fixed to the sole bar, and the arrangement of internal coil, or ferrules, and external hoops, is the same as previously described, with this exception, that one binding hoop only is used on each cylinder instead of two, in the case of waggons, rather greater elasticity being required for carriages. Some new passenger carriages with this description of spring are now in use on the Monmouthshire Railway.

Fig. 7, Plate 10, shows the present improved form of Engine-Bearing Springs, termed the Hydro-Pneumatic Spring. The object of this form is to obtain the same amount of elasticity with a less quantity of India-rubber, and is accomplished by thinning the cylinder of India-rubber AA internally, and in the increased space thus obtained placing a quantity of fluid B—water is used for this purpose—which, acting by hydrostatic pressure, distributes the pressure equally over every part of the internal surface, thus obtaining a much larger bearing surface than if the pressure were confined to the ends, and in fact producing precisely the same effect as a solid homogeneous cylinder of India-rubber. The fluid does not entirely fill the cavity in the India-rubber, at least not when first put in, but is adjusted to do so only on the spring receiving the maximum of impact; the air at the same time, which had before occupied the space left vacant by the fluid, retires into a chamber C for that purpose in the upper part of the casting, and being then in a state of considerable condensation, exerts a powerful elastic force, assisting the spring to regain its equilibrium. The air and fluid are prevented from escaping under the ends of the India-rubber cylinder by that part

of the casting which receives them being cast with a groove, so that on the application of pressure, the India-rubber forces itself into the minutest crevice, and a perfectly tight joint is obtained without the necessity of interposing any other substance.

A spring on this principle is applied to waggons in the same manner as the spring in Fig. 3, of very simple construction, and one that requires no alteration of horn plates or axle-boxes, but which, with a very little labour, may be applied to any existing waggon adapted for steel springs.

Fig. 8 shows the same spring, as applied to some new engines, now being made for this railway. In this case the spring is entirely beneath the footplate, in a hollow part of the framing, immediately above the axle guides, by which great compactness is obtained with increased strength of the frame. The internal arrangement is the same as shown in Fig. 7, but the spring piston DD is here cast in one piece with the axle-box, thus avoiding the necessity of using a spring pin, and at the same time dispensing entirely with suspending links, nuts, and bolts, thereby still further reducing the total weight of the spring, which in this case is brought to a minimum.

Fig. 6, Plate 9, represents the Pneumatic Buffer, in which the elasticity of a cylinder of India-rubber AA is combined with that of a column of enclosed air B. No fluid is used in this case, the position of the buffer and its mode of action not being favourable to its use; neither is it required, as buffers should be sensitive, more so than would be the case were fluid used. The transverse pins CC, riveted to the external or wrought-iron cylinder, serve to confine the fixed and moving part of the buffer, and pass through slots in the plunger to allow them sufficient play. In a cheaper form of this buffer, the external wrought-iron case D is replaced by a cast-iron one, for use where not liable to severe cross strains, Fig. 6 being only for extra strong buffers.

Fig. 5 shows a Draw Spring for the buffer plank of an engine, and Fig. 9, Plate 10, is a cheaper form (though equally efficient) for common waggons; and these are alike in principle, and only differ in their form and getting up.

The advantages resulting from the use of these springs may be thus enumerated:—1st, Reduction of Dead Weight. This item is more

extensive than appears at first sight, since the reduction of weight is not confined to the springs themselves, but extends, in a greater or less degree, to a variety of other parts of the engine, carriage, or waggon, on account of the smoothness of their action. This is particularly advantageous in the case of cast-iron, whose liability to fracture consists, not so much in the weight it has to carry, as its inability to resist strains, jerks, and concussions; these are, however, nearly altogether deadened by the use of these springs, so that a motion uniformly smooth and steady takes the place of one that is very injurious to railway plant, especially to engines; and as the working portions of an engine are made extra strong, with a view to resist the concussions they are subject to with steel springs, it follows that when these are no longer allowed to operate, they may be made lighter without in the least impairing their efficiency. The reduction in the springs themselves is, however, considerable; and the weight thus gained is valuable, particularly in the case of waggons, where it becomes available for tonnage. The amount of this reduction of weight varies, as shown by the following table, but may be taken on an average at from 3½ to 5 cwt. per engine, and the same for waggons.

Comparative Weight of India-rubber and Steel Springs.

Weight of Springs.	India Rubber.	Steel.	Reduction in Weight.
Engine-Bearing Springs.	Cwt.	Cwt.	Cwt.
India-rubber, 1¼ cwt.	4¼		
Iron Work, 3 cwt.			
Steel Springs taken off		8½	4¼
Engine Hydro-Pneumatic Springs.			
India-rubber, 1 cwt.	7		
Iron Work, 6 cwt.			
Steel Springs taken off		8½	1½
Tender-Bearing and Draw Springs.			
India-rubber, ¾ cwt.	2¾		
Iron Work, 2 cwt.			
Steel Springs taken off		11	8¼
Carriage-Bearing, Drawing, & Buffing Springs	4½		
Steel Springs taken off		9¾	5¼
Waggon-Bearing, Drawing, & Buffing Springs.	3½		
Steel Springs taken off		8¾	5¼

2ndly, Steadiness of Motion. This has been referred to before, and it may be added that the great steadiness of the engines with the India-rubber Springs is the surprise of every one who has witnessed their performance upon the imperfect road on which they are worked.

3rdly, Durability. Although sufficient time may not have elapsed to test the absolute durability of these springs, yet during the time they have been in use, in consequence of the heaviness of the work, if deterioration had commenced ever so slightly, it would have been observable; but in a large number of the India-rubber Cylinders that were examined, after being at work for various periods, varying from four to six months, in both engines, carriages, and waggons, in no instance was the slightest alteration visible from the day in which they were first used, nor the slightest permanent contraction in length or expansion in diameter perceptible: it may, therefore, be inferred that their durability far exceeds anything hitherto applied to the same purpose, and is fully equal to any reasonable expectation or requirement. The specimens before the meeting have been in use for the last five and six months, and corroborate this statement. The weight on each pair of the engine springs is from 4½ to 9¼ tons.

4thly, Saving in Repairs. The simple construction of these springs renders it almost impossible for any injury to happen to them, consequently little or no repairs are needed. As stated before, the cost of repairing the steel springs of fifteen engines for six months was £251 9s. 9d. The cost of repairing the India-rubber Springs of fourteen engines during the last six months was only £1 18s. The saving in the cost of repairs is not confined to the springs alone, but the engine itself, the carriages and waggons to which they are applied, and even the permanent way, share the advantage. It is found that fewer chairs are broken, fewer rails (plates rather) are bent, less grease and oil is used for the bearings, and the cost of maintaining the waggons is reduced when India-rubber is used. It is inferred with a considerable degree of probability, that from the absence of any jerk upon the axles, the tendency of the iron to become crystallized or altered in its nature and suddenly fracturing, so often complained of, and which has produced so many serious accidents upon railways, will by the use of these springs be nearly overcome, and the axles remain perfect for a much longer period, more especially as under the India-rubber Springs they show no tendency to heat.

5thly, Cost. The question of first cost does not properly belong to this paper, but it will be sufficient to state that a well-constructed India-rubber spring ought not, in any case, to exceed the cost of a steel spring of equal strength; but on the hydro-pneumatic principle it will be found to be considerably cheaper, especially for engines, amounting on an average to twenty per cent. saving on the old plan.

The foregoing remarks have been made chiefly with reference to Bearing Springs, but they apply equally to both Buffer and Draw Springs; and in proportion to the extent in which India-rubber is used in place of steel, does the improvement in the rolling stock become apparent, and the benefits resulting from its use more strongly developed. The Pneumatic Buffers, it is considered, have been subjected to a peculiarly severe test, few lines of railway in the kingdom possessing such disadvantageous circumstances. Almost every other description of buffer had been tried previously with the same want of success, until, from repeated failures, the attempt to obtain a permanent buffer was almost abandoned in despair, and solid blocks of wood were substituted for them in many instances. With these buffers, however, no failure has taken place, nor in any instance has their elasticity diminished in the slightest degree. In the accompanying table, the deflection of this description of buffer and the several kinds of springs, under different weights, is shown.

Table of Deflection of Springs.

Load.	Engine Single Spring.	Engine Triple Spring.	Engine Hydro-Pneumatic.	Waggon Spring.	Buffer Spring.	Draw Spring.
	Fig. 1.	Fig. 2.	Fig. 7.	Fig. 3.	Fig. 6.	Fig. 9.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
$\frac{1}{2}$ ton.	$\frac{5}{6}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{16}$	1
1st ton.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$
2nd ,,	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	1
3rd ,,	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{8}$
4th ,,	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{16}$	—	$\frac{1}{8}$	—
5th ,,	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{16}$	—	$\frac{3}{16}$	—
6th ,,	$\frac{3}{8}$	—	—	—	$\frac{3}{16}$	—

Before the application of India-rubber draw springs to the engines and tenders, the couplings were frequently breaking, and also the frame

ends; but since their adoption nothing of the kind takes place. Such are the advantages of these springs that their adoption promises to become general, and it will be shortly, without doubt, as rare to meet with a waggon unprovided with a draw spring, as it was formerly to meet with one.

In working 15,000 miles, the cost of repairs is found to be reduced in the engines using India-rubber springs, in corresponding engines of the two classes, from 5¾d. to 3¾d. per mile, and from 7d. to 3¼d. per mile.

It has been the writer's object in this paper to state rather what has been done than to speculate on what will be; but it is notorious that the ordinary steel springs are deficient in point of general efficiency, whether as regards elasticity, durability, or cheapness. It may be that competition may cause their manufacture to be less strictly attended to than formerly; or it may be, and most likely is, that the requirements of the present day have outstripped their ability to perform. However, be that as it may, it is well known that a substitute which shall combine the above requisites has been long desired; and the writer's hope, therefore, that this desideratum will now be supplied by the springs which have been described must be his apology for bringing the subject before the Institution.

Mr. Craig exhibited a set of the different descriptions of India-rubber Springs described in the Paper, and also specimens of the India-rubber Cylinders, taken out of various springs which had been at work on the Monmouthshire Railway, to show the effects of wear upon them. One cylinder had worked 8,850 miles in the bearing spring of an engine; another 14,060 miles in a carriage bearing spring; and an engine buffer spring that had been six months in constant use; all of them appearing uninjured by the work, not having suffered any permanent compression.

Mr. H. Wright observed that he had seen these India-rubber Springs at work on the Monmouthshire Railway, and they certainly worked very satisfactorily, and were much better adapted to that situation than steel springs. The case of that railway was

very peculiar; it was perhaps the worst in the kingdom for destructive action on the springs, from the great inequality and roughness of the road, which was not upon the edge-rail, but the old tramway system, and with very sharp curves; it was, indeed, impossible for steel to stand in the engine springs, and the steel springs were disabled very rapidly; but the India-rubber Springs appeared to stand the work well.

Mr. W. A. Adams said he was acquainted with these India-rubber Springs, and had witnessed their working on the Monmouthshire line; it was previously impossible to keep steel springs in order, from the violent jerks they were subjected to, and the substitution of India-rubber for steel in that case was an important improvement. As to the general application of India-rubber Springs, there was a special circumstance in favour of their use in locomotive engines, from the confined position and the want of space to fix a properly proportioned laminated steel spring, which might probably be otherwise made to work satisfactorily; but the steel springs generally used in locomotives were so short and stiff, that their elastic action was exceedingly imperfect, and they were consequently ill suited to withstand the violent concussions of a rough road. In the bearing springs of carriages the case was very different, and a long thin laminated spring was employed, which had a very easy, elastic action, so that in that case the advantage would be less felt of the substitution of India-rubber for steel. In applying the India-rubber Springs to carriages, it had to be observed that the bearing of the frame would be on four points only, instead of eight, requiring a stronger frame or cross-bars to distribute the strain.

Mr. Allan said he had made some trial of these India-rubber Bearing Springs on engines, and they worked very well—but he found them too elastic and liable to produce a jumping action; but the springs he had tried were of the kind first described, without provision for checking the rebound of the spring.

The Chairman inquired whether, if such re-action could be removed, the India-rubber Spring would be considered superior to steel?

Mr. Allan thought that very little friction or resistance would be sufficient to check the re-action, and the India-rubber would then certainly make a very good spring.

Mr. Craig observed, that the rebound complained of was quite stopped by the little resistance offered by the small second spring that had been subsequently introduced, but it was now found that the objection was quite removed by the water application in the new Compound Spring.

Mr. Clift inquired whether any difference was found between winter and summer in the action of the India-rubber? whether there was any more oscillation observed in hot than in cold weather? and whether the India-rubber was liable to any injury by the heat to which it was liable to be exposed from the boiler or fire-box of the engine?

Mr. Craig replied, that the India-rubber was not affected by the temperature, and no effect was found during the last severe winter; also in two tank engines one pair of the India-rubber Springs was exposed to great heat, probably as much as 240°, being very near the fire-box, but there was no perceptible effect. The material used for the springs was Molton's Prepared India-rubber; the raw gum would not stand exposure to heat, and the constant compression and elastic action.

The Chairman inquired what pressure there was upon the India-rubber when the springs were at work?

Mr. Craig replied, that the vertical pressure on the end of the India-rubber Cylinder, in the engine bearing springs, amounted to about 1½ cwt. per square inch; a weight of 4½ tons being supported on a cylinder 9 inches diameter, having a 1¾-inch hole in the centre. In the Hydro-Pneumatic Spring the pressure on the India-rubber was about 2 cwt. per square inch; he intended trying the exact pressure of the water with a Bourdon's Pressure Gauge, but had not been able to complete the experiments in time for the present meeting.

Mr. E. A. Cowper observed, that he understood a considerable trial of India-rubber springs had been made on engines upon the London and North-Western Railway, and inquired what kind of spring had been applied there, and what were the results? He had

also heard that on the Great Western they used India-rubber Springs, and now never hung an engine any other way.

Mr. Craig replied that the springs tried on the London and North-Western were with two or three cylinders of India-rubber, similar to the first arrangement described, and they were working very satisfactorily, and he believed were preferred to steel springs.

The Chairman inquired the relative cost of India-rubber and Steel Springs?

Mr. Craig said that the cost of the India-rubber Springs did not in any case exceed that of steel. Waggon springs were about £3 18s. per set, but engine springs were considerably less expensive than steel, there being so much greater proportionate weight of steel in the ordinary springs. By the introduction of water in the Improved Springs, the quantity of India rubber to support the same weight was reduced from 20 lbs. to 12 lbs. in each spring, which, at the cost of two shillings per pound, effected a considerable saving in the expense.

Mr. H. Wright observed that he was now making a number of waggons with the India-rubber Bearing Springs, in which a compact and economical arrangement of the spring was adopted, applicable to the ordinary construction of waggon frames. A specimen of the spring and axle-box was exhibited to the meeting.

The Chairman asked whether it had been found that an actual saving in oil or grease was effected by the use of the India-rubber Springs?

Mr. Craig said that considerable saving in this respect had been observed, but he was not able to give the exact results, and he would make a comparative trial for the purpose of ascertaining it; he considered that the removal of the harsh jerks that occurred with the rigid steel springs prevented waste, and caused the lubrication to be more perfect.

The Chairman observed, that he hoped Mr. Craig would continue his experiments on the application of India-rubber to Springs, and report the result at a future meeting; he proposed a vote of thanks to Mr. Craig for his Paper, which was passed.

The following, by Mr. W. Bridges Adams, of London, was then read :—

ON RAILWAY AXLE LUBRICATION.

In the economy of railway transit an idea has prevailed that increase of speed increases cost in a compound proportion, in many other things than the mere excess of fuel consumed in the locomotive. This is correct only in reference to imperfect appliances. If, for example, the rails deflect beneath the rolling loads, the substructure will be displaced, and increased speed will greatly increase the displacement. If the wheel peripheries be out of order, the greater the speed the greater will be the destruction; and so also if the rail surfaces or joints be out of order. And in proportion as the springs are inefficient, *i.e.*, are non-elastic, or do not act through sufficient space to moderate the shocks, so will the destructive wear be increased by increased speed. But were all parts of the system—ballast, sleepers, rails, wheels, axles, journals, bearings, lubrication, and springs—rendered as perfect as is within the scope of mechanical art, there seems to be no reason why increased speed should involve any extra cost beyond the increased consumption of fuel, oil, and grease, provided all parts of the system be proportioned to each other.

In increasing speed with imperfect mechanical arrangements, one of the most prominent difficulties occurs in preventing axles and axle-boxes from heating; the cause of the heating is in the imperfect lubrication. The word lubrication literally signifies slipperiness, but this does not express the precise action. Oil, or grease, or soap, interposed between two metallic bodies moving one upon the other, is composed of a series of small globules, which keep the bodies separated, and serve as rollers. The surfaces of metallic bodies, however apparently smooth, are composed of salient and re-entrant angles of larger or smaller size, according as the metal is hard and polished, or soft and rough. Therefore the more imperfect the structure of an axle and bearing, the more viscid must be the lubricating material to keep them from contact. If the cushion of lubricating material be insufficient in extent, contact ensues between the salient angles of the metal, and heating takes place to such an extent as to boil away the lubricating material and drive it off.

In calculating the surface bearing of axles, there are two circumstances to consider. First, the actual weight to be borne; and, secondly, the amount of concussion adding to the effect of the weight, which latter will much depend on the efficiency of the springs to moderate the effect of the shock.

Before the advent of railways, mail coaches and private carriages, with a maximum weight of 3 tons, were constructed with axles case-hardened, and with a bearing surface on each arm equivalent to 30 square inches. This is equivalent to about 56 lbs. per square inch on the bearing.

Mr. Nicholas Wood, in his experiments on axle friction, found that with the best oil and with favourable circumstances, a superincumbent weight of 90 lbs. per square inch gave the minimum of friction.

Some of the earliest railway axle-bearings were 4 inches in length by $2\frac{1}{4}$ in diameter, something under 14 inches of total bearing surface, fitted according to Mr. Wood's calculations, only for a waggon of 2 tons total weight. It would seem as though these sizes had been calculated from the fixed shafting of factories, without any calculation of concussion. Probably this was the reason why viscid soap was substituted for fluid oil, increasing the toughness of the material used for lubrication to make up for the want of bearing surface. In railway practice it is found that the soap or grease which serves well in the winter, is too fluid in the summer, a sure proof that the bearing surface is far too small for any lubrication with oil, which offers the minimum amount of friction. A strong objection to soap lubrication is, that it requires a considerable amount of friction in the winter time to make it fluid; and it is sometimes difficult to start a train into motion when the grease has been frozen.

In the wheels of highway carriages, the oil chambers are contained within the wheels, and revolve with them, which process involves the efficient lubrication of the axle. In the axle-boxes of railway carriages the grease or oil does not revolve. In the highway wheels, the oil always has a tendency to rest in the well or magazine below the level of the axle. In the ordinary axle-boxes of railway carriages the grease or oil is above the level of the axle, and as the axle revolves, the oil or grease, or rather the grease (oil not being used, except in engines)

passes through a hole or holes in the bearing-brass, which lies on the upper half of the axle; and thus the process is like that of a hand-mill, the lubricating material is supplied on the upper surface of the axle, and passes away at the lower like grist. To make the lubrication more certain, the holes are of large size, and this involves an evil by diminishing the bearing surface at the most important point. If these holes get stopped, the lubrication ceases and heating ensues; and there are no means to remedy the evil, save by lifting the bearing from the axle and inserting more grease.

Thus, in the ordinary railway grease-box, there is not only a great waste of grease, but also a very imperfect mode of securing lubrication. The well-made, case-hardened axles of a common road carriage are capable of running 5000 miles over a bad road with once oiling, with a small quantity of oil, while railway axles require greasing every 100 miles or less, with some few exceptions.

Impressed with these imperfections, the writer some years back began to consider the best means of remedying them. It was evident that the only mode of applying grease or oil to a large surface of the axle-bearing was at the under side. In the common mode of an open bottom, this was scarcely practicable, and the question was, could the bottom be effectually closed without so confining the axle as to make partial heating dangerous. This was accomplished by applying a flexible connection between the axle and the inner side of the axle-box, and making the bottom of the box tight. In this mode, the grease filling the lower part of the box, the whole under surface of the axle was bathed in it, while all dirt and grit were excluded. Moreover, the grease being as it were in a well below the axle, any accidental extraneous matters could sink to the bottom, and not be brought in contact with the wearing surface. And supposing the upper holes to be entirely stopped, lubrication would go on notwithstanding. It must be evident that feeding from above in all cases involves the chance of dirt getting to the axle, which feeding from below obviates.

To provide against accidental injury to the axle-bearings, the writer provided also for a mode of shrinking on a false bearing upon the axle arm, so that in case of cutting it might be removed and replaced. The following is a description of the axle-box invented and patented by the writer, in May, 1847, which is shown in the accompanying drawings.

Fig. 1, Plate 11, is a longitudinal section, and Fig. 2 a transverse section, of the axle-boxes employed on the North Kent line. The top of the box is circular for a peculiar arrangement of springs; the box is cast open-fronted with a moveable front A to attach by screws, a grease-tight joint being maintained by an elastic substance between. In this mode the interior of the box can be inspected, and a new brass applied, without lifting the carriage. The back of the box round the axle is cast with a round-edged projecting lip BB. A plate of metal CC, with a centre hole fitting the axle, is secured by bolts to the back of the box, with a piece of leather DD, the orifice of which is enlarged into a partial pipe form round the axle, to give increased bearing surface. This leather presses equally on the axle and on the lip of the box, and thus a tight joint is maintained, which preserves the grease without overflowing above the level of the bottom of the axle. The bolt-holes in the metal plate are oblong vertically, so that when the upper bearing brass wears and causes a corresponding wear in the plate and leather, and a consequent leak below, the two latter may be drawn upward to fit the lower part of the axle. At the top of the box there is a screw tap E for feeding, with holes through it to admit the ingress and egress of air. This tap serves to feed an upper chamber F, with holes to the axle as usual, and also to feed the lower chamber G, which in addition catches the grease that falls through from the upper chamber by the working of the axle. A piece of hard wood H is applied between the end of the axle and the front of the box, to prevent wear of the shoulder collar of the bearing brass. Two rollers of light wood, II, float on the oil or grease in contact with the lower side of the axle, and thus carry up the lubricating material if it happens to be below the level of the axle.

Figs 3 and 4 are a longitudinal section and back view of an axle and axle-box, also for an upper and lower feed. To retain the grease or oil, a conical metal spring CC is inserted in a corresponding circular groove at the back of the box; by its elastic expansion it presses against a strip of leather lining the groove, and thus forms a tight joint. The small end of the conical spring clips a leather pipe-collar DD, fitted on the axle, which collar may either revolve with the axle in the small end of the spring, or it may be fixed to the spring and the axle revolve within the leather collar; as the spring expands against the

groove in the box, it has no tendency to press the axle or leather too tightly, so as to cause friction. The conical spring is prevented from turning by a stud; the edges of the spring overlap each other to keep out dirt, and the hollow space between the spring and the axle may be filled with sponge or cotton waste.

Figs. 5 and 6, Plate 12, show a longitudinal section and back view of an axle-box on a similar arrangement, in which a conical pipe of blocked leather CC, is secured to the box lip by an elastic ring DD, similar to a key-ring, and clipped to the axle by a second ring EE. Both the spring cone and the leather cone will by their free action accommodate any irregular movement of the box, and prevent loose wear between both them, the metal plate, and leather. In all cases where any material comes in contact with the revolving axle, it is essential that the surface be properly smoothed, that the pressure be as light as may be convenient, and the lubrication certain.

Fig. 5, in addition to the axle-box arrangement, shows a mode of applying moveable journals to axle-arms, either new or old. Thus the journal AA, may be forged down to a taper, with the object of extending the distance of the bearing from the wheel, or of increasing the diameter of the axle-bearing. The moveable bearing BB, may be of wrought-iron, or cast-iron well got up and case-hardened; and manufacturers might be enabled to supply a superior class of axle-box and bearing cheaply. Railway Companies might thus be enabled, at comparatively little cost, to replace their axles when rendered unsafe by long vibration in running. The hollow axle, shown at Figs. 7 and 8, would be well adapted to this arrangement.

Great numbers of these boxes, with leather collars, have been applied, and have been found to answer the desired purpose.

It should be remarked that it is desirable in all cases to get the axle-bearings as long as is convenient, even when not required for bearing surface, for the following reasons:—The points of the springs which support the frames are at a considerable elevation above the axle-bearing, and act with mischievous leverage to tilt the axle-boxes laterally to the carriage, when the wheel flanges strike the rail. It is evident that unless there be some proportion in the length of bearing to the

height of the spring, there will be a great strain upon the guards of the axle-boxes to keep them steady.

The axle box described above is the first application of the principle of retaining the grease or oil, by closing in the back of the box.

Since the above described, similar contrivances have been brought out by various other parties for the purpose of retaining the grease in the axle-boxes, but it appears that the original application of the principle was that of the writer, in May, 1847; and there does not appear to be any material variation in any of the subsequent plans.

As to the practical mechanism for keeping out dirt and preserving the bath of grease, it must vary with circumstances. Many axle-boxes are so close to the wheel bosses, that the leather pipe collar is the only practicable arrangement, and having come into general use, it is difficult to vary, but the writer prefers the elastic metal collars, CC, shown in Figs. 3 and 7, pressing upon leather pipe-collars DD.

The object sought is to form a tight joint between the box and the axle, which are both exposed to rough jolts and a tilting movement of the box on the axle; therefore the medium to form the joint should be flexible, and not liable to be put out of order.

The mode of lubrication from above the bearing has one objection, in the liability to accident by dirt getting on the arm, and from the holes wasting a most important part of the bearing surface; but the writer thinks it preferable to retain it, keeping the holes small, but merely as a security in case of any accident happening to the lower reservoir.

Two forms of journal are shown in the diagrams; one the double cone, Figs. 5 and 7, the other the ordinary cylindrical journal with collars, Figs. 1 and 3. There is an advantage in the double cone with the small diameter in the centre of the bearing, that it has a tendency to cause the lubricating fluid to press outwards from the centre while in rapid motion. The cylindrical bearing between collars has also this disadvantage, that the box is not kept in its position by gravity, but by a very small collar surface, which being vertical does not retain the lubricating fluid so easily as the horizontal surface; and, moreover, by its larger diameter has a tendency to throw it off by centrifugal action. Where the boxes fit tightly to the guards, the collar-bearings are frequently subject to rapid wear, and lateral

thrust is more destructive than the downward pressure of the load. The small rounded corners next the collars, intended to prevent the "nicking" or breaking of the axle, are of little service to give the box a centripetal tendency. The cylindrical bearing has the advantage, that the bearing surface is not lessened by end play, and with the axle working in a bath of lubricating material, the collars will at all times be safe enough. In either case, of the cone or the cylinder, it is clear that the lubricating bath below will be the safest precaution against heating. As regards the strength of the axle, the coned journal has the advantage by its gradual tapering form, supposing an equal amount of metal in both cases. The fitting of the wearing brass to the journal is a matter of greater nicety with the cone than with the cylinder; with cylindrical journals the usual practice is to make the bearing brass of considerably larger radius than the journal, so that it bears on a very small surface, which wears to a polish, and gradually extends to the half diameter. In point of fact, railway bearings are made to grind themselves to a true fit or work, instead of being accurately ground and fitted beforehand, as is the case with nicer machinery.

The Chairman inquired what comparative results were obtained as to consumption of grease in the axle-boxes tried on the North Kent line?

Mr. W. B. Adams said he understood that the axle-boxes worked very satisfactorily, and with a reduced consumption of grease, but he was not able to give the results of the economy, as an exact comparison had not been made.

The Chairman observed that there appeared some difficulty in the conical spring proposed, for the purpose of making a close joint between the box and axle, and inquired whether it had been found to have sufficient elasticity to work well?

Mr. W. B. Adams said that the only plan which had been practically tried, was the leather collar first described; he had not yet applied the conical spring, because there was not in many cases space enough to get it in between the axle-box and the nave of the wheel,

and therefore the leather collar only had been used, which had the advantage of taking up less space; but he thought the conical spring was preferable, and would make the most perfect joint, and there would be no difficulty in adopting it in modern carriages, as the projection of the axle from the wheel is now commonly extended to increase the width of the bearing.

The Chairman inquired how the grit was found to be kept out in Mr. Allan's Sponge Axle-Box, that was described at the last meeting?

Mr. Allan said that his axle-box was designed for using oil instead of grease; the only way dust and grit was kept out was the proximity of the nave of the wheel to the face of the axle-box, but it was found that the sponge prevented the grit from penetrating more than a short distance, about an inch or an inch and a half along the journal, as shown by the sponges when taken out.

Mr. E. A. Cowper remarked, that it was an important desideratum to get a grease-tight joint at the back of the axle-box, that would effectually keep out the grit, and not be interfered with by wear and the motion of the box; and he thought that such a joint had yet to be accomplished. In the American Axle-Box described at a recent meeting, the leather flange working in a groove on the axle, appeared a simple means for attaining this object, but some elastic provision for following up the wear was also wanted; this was proposed to be effected by the conical spring, though that plan might admit of further improvements, as there was generally very little room between the wheel and the axle-box.

Mr. W. B. Adams thought that some good plan was certainly much wanted, for efficiently closing the back of the axle box, and there was not such a one in use at present; he thought the three or four inches space now usually left between the nave and axle-box, would be sufficient for the introduction of the proposed conical spring.

The Chairman observed, that it was a very important point to get the grit thoroughly shut out, and a good combination might perhaps be made of some of the plans that had been proposed for the purpose; any experiments on lubrication were interfered with in the results by the entrance of grit.

Mr. W. B. ADAMS remarked the difficulty of making exactly parallel experiments on the lubrication of railway axles, from the number of disturbing circumstances, in the variation of weight and uniformity of bearing on the journals, and in the attention to the lubrication, and the difficulty of getting the exact mileage.

Mr. LEA suggested the experiments to be made at the same time on opposite sides of the same carriage, so as to have them under similar circumstances.

The CHAIRMAN said he hoped Mr. Adams would pursue the subject, and give them further results; and he proposed a vote of thanks to him for his Paper, which was passed.

The following Paper, by Mr. John Lea, of London, was then read :—

ON A NEW LUBRICATING MATERIAL.

Whilst extensive and valuable improvements have been made in the construction of the locomotive stock of Railways, but little progress has been made in economizing the cost and improving the efficiency of lubricating the numerous moving parts of this extensive property. Since the first establishment of Railways, scarcely any change has been effected in the character of the materials employed for this important purpose ; oil and tallow were originally adopted, and are still almost universally employed in the more important department, the lubrication of locomotive Engines, to which department the subject of the present paper has more particular reference. The more limpid lubricating materials are wanting in consistency to resist pressure, and the more solid fats want fluidity to make them available under ordinary temperatures. The varieties of oil have, consequently, been at all times the common resource ; but even the majority, if not all of these want the perfect properties requisite for faultless lubrication.

Both animal and vegetable oils of every kind contain native impurities which materially qualify their efficiency. Many of them contain earthy matter, which soon becomes converted into a viscous, impeding, and exciting substance, of such consistency that produces

rapid abrasion of metallic surfaces, and consequently, causes such increase of temperature as seriously tends to disintegrate or soften the metallic body. All oils contain more or less of watery particles, which produce oxidation of the necessarily polished surfaces of the motive parts of machinery, and thus gradually wear them away, whilst the fluid itself becomes vitiated by its own action. As a further characteristic, it may be observed, that those oils most in repute as lubricants, are of such limpid consistency, that they become inevitably extensively wasted by escapement. The desideratum, therefore, for this important purpose, is clearly, some agent which shall possess all the necessary properties of smoothness and body, with adequate fluidity, and without the impurities and other defective characteristics of raw oils.

The new lubricating compound that is the subject of the present paper, is composed of carefully refined southern whale oil as a basis, to which are added India-rubber and levigated white and red leads, to constitute a kind of metallic soap, possessing the necessary oleaginous lubricating property, adequate fluidity, and a body impenetrable by the pressure upon ordinary bearings. The oil is heated to from 400° to 500° Fahr., and India-rubber cut up fine is then added, to the amount that the oil will dissolve, less than 50lbs. per ton of oil being sufficient; after the oil has become completely saturated with the India-rubber, the temperature is considerably reduced, and equal proportions of finely powdered red and white lead are added, at the rate of about 25lbs. of each per ton of oil.

The mineral ingredients perform the office of "vulcanizing" the compound, and presenting in use, a microscopic non-conducting stratum of separation of the bearings, which precludes friction, and consequently, heating and dissipation. In using the term "vulcanizing" it is intended to express the property of resisting any material change of consistency through any ordinary range of temperature, and it is found that the consistency of this compound does not observably alter through the extreme range of our English climate.

If there be no metallic contact between two surfaces, there can be no friction between them, and consequently, no elevation of temperature; and in the absence of undue heat there will be no excessive dissipation of the lubricating material, by volatilization. In the experiments made with this compound, it has been found that no pressure of bearing, or extreme of velocity, ever penetrated its substance, or produced any perceptible rise of temperature, and though it is gelatinous and as smooth as oil, its elastic body prevents penetration or displacement. It works freely with ordinary worsted or cotton syphons when the Engines are in motion, but ceases to flow when they are stopped, avoiding the waste of continuing to flow, to which limpid oils are liable. All the experiments made with the new compound under similar conditions have resulted uniformly, and it may be sufficient to quote in detail, an experiment made on the Manchester and Crewe Station of the London and North Western Railway. In this instance the new compound was applied to one of the Express Engines, (No. 15,) and another Engine, (No. 8,) of similar character, and performing equal daily service, was submitted to a careful comparison with Oil and Tallow. These experiments were continued over many weeks, and the following results were reported by the Engineer.

It has to be observed that the prices of oil and tallow were not then materially different to their present cost, but the quoted price of the new compound has been since reduced to one half. The distance run by the Engines in these experiments was about 2340 miles each, in the eighteen days referred to; the cost of oil and tallow was found to be nearly *Fourpence per journal*, per 1000 miles, whilst that of the new compound was scarcely more than *one Penny* for the same work, and would be at the present reduced cost only *one Halfpenny per journal, per* 1000 *miles*. This new compound is considered to possess lubricating properties much superior to those of any other natural or manufactured article, involving, as it does, remarkable efficiency combined with economy of cost; and it has the important advantage also of only requiring to be supplied at long intervals, thus preventing almost the possibility of accident arising from the exhaustion of the supply in the course of any single journey.

The author of this paper recently obtained from a number of Railways statements of their average cost of lubricating locomotive engines and tenders, and the general result showed an average cost of about *one Shilling* per journal per 1,000 miles, the range of cost being very limited, as none exceeded fourteen pence per journal for that distance, nor is any under eleven pence, including in all cases the lubrication of the other parts of the machinery, besides the axle journals.

Mr. Lea exhibited a specimen of the lubricating composition, and explained that the India-rubber, the ingredient on which its qualities mainly depended, caused the dark colour, and the composition was made of different degrees of thickness, to suit the different kinds of bearings, by varying the proportion of the red and white lead. In the manufacture of the composition the oil took up only a limited portion of the India-rubber, which was soaked in it whilst at the boiling point; the red and white lead were then added, simply in mechanical mixture, and thickened the compound to the degree required. He mentioned that the composition had been patented by Mr. Donlan, in 1848, but had remained dormant till the present time, when he, Mr. Lea, had taken it up.

The Chairman inquired whether there was any tendency to settlement of the heavier ingredients in the composition, and whether it was applicable to the ordinary oil cups, with syphon wicks.

Mr. Lea replied that no settlement was found to take place in the composition, after standing for some months; the thinner kind flowed as freely as oil in the ordinary syphon cups, and the thicker kind was adapted to the bearings of heavy shafting, and was found to keep them cool in cases where water was otherwise required.

Mr. Everitt inquired the effect of cold weather upon the composition, and what the expense of it was?

Mr. Lea said it was found to work as well in cold weather as in hot: the cost of it was Sevenpence or Eightpence per pound, but the proportionate quantity used was found to be considerably less than of oil or grease.

The Chairman proposed a vote of thanks to Mr. Lea for his communication, which was passed.

The following paper, by Mr. T. T. CHELLINGWORTH, was then read :—

ON MESSRS. COX AND WILSON'S PORTABLE SINGLE-ACTING STEAM ENGINE.

The subject of the present paper is a small Portable High-Pressure Steam Engine, differing from other engines of the kind, mainly, in the simplicity and economy of its construction, the small number of its parts, and the consequent diminished liability to derangement, and greater durability.

An engine similar to the present one was suggested some four years ago, by Mr. J. W. Wilson. It consisted of a solid plunger working in an oscillating cylinder, the steam acting only one way ; the engine was partly drawn out at that time, but no further steps were taken, until the subject was again brought forward, recently, and a drawing was made by the author, who introduced the self-acting trunnion valves, as being more simple and less expensive than the slide-valve and gearing. One of these engines was made and set to work at the Oxford Works, in September, 1852, and has been at work ever since, and is now in as good order as the first day it was started, although running at an average rate of 150 strokes per minute.

This engine is shown in Plates 13 and 14, and one of the engines is exhibited on the table.

Fig. 1, Plate 13, shows a side elevation, with the trunnion in section.

Fig. 2, a front elevation, with the cylinder and trunnion in section.

A is the cylinder of cast-iron, bored out its whole length, the bottom screwed in, and the trunnions B and C cast on. In the trunnion C are the steam ports, shown in the cross section at D ; the steam-way E connects the ports in the trunnion with the bottom of the cylinder. F is a cast-iron plunger packed with hemp and connected to the crank G ; H H two A frames, I the fly wheel, L the steam pipe, K eduction pipe.

In Fig. 1, the engine is shown taking in steam, the plunger being at half stroke and the steam-way open; and in Fig. 4, the engine is

exhausting and the eduction port open. In the working of this engine, the steam forces up the plunger, the inertia of the wheel assisted by the weight of the plunger bringing it down. As it is single-acting, the pressure is always on the valve, working in fact like an ordinary slide valve, only on a curved instead of a flat surface.

This engine has worked with the cap of the trunnion plummer-blocks removed, without leaking.

Fig. 5, Plate 14, shows the general arrangement of the engine and boiler fixed on wheels, and Fig. 6, a section of the boiler. The boiler O, is set in a cast-iron box with fire bricks, the fire being under the boiler at P, and returning through the two tubes Q Q. R is the water gauge, consisting of a piece of tube working in a stuffing box; a cock is fixed on the side of the pipe with the end turning down into the tank S, from which the engine draws its water. When it is required to ascertain the height of the water in the boiler, this cock is opened, and if it blows steam the tube is pushed down till it reaches the water, if water, it is raised till it blows steam, and the level of the water in the boiler is indicated by the graduations upon the tube, forming a very simple and cheap water gauge.

The principal advantages claimed for this engine are, its simplicity of construction, and consequent cheapness, and the very slight probability of its getting out of order, even in the hands of an inexperienced person, together with its compactness and portability.

Some of the purposes to which it is proposed to be applied, are as follows:—

When placed with a boiler on wheels, as shown in Fig. 5, to be used in a factory where a number of machines are driven by a large engine; now if it is required to do some overwork, in which, as is often the case, it is only necessary to drive one or perhaps two lathes, or other machines, this engine may with a very little trouble be wheeled up to its place and set to work, and the expense of running the large engine and shafting be saved.

Also, in repairing the large engine in case of a break-down, a great saving of time will be effected in not having the work done out.

For a donkey engine for feeding the boiler of marine and locomotive engines; and as a pumping engine for tank houses at Railway Stations, or other purposes. In this case it is proposed to place the pump in a similar position to the steam cylinder, but opposite, on the other side of the frame, and to work the pump by a crank, the two cranks being in opposite directions, so that the steam pressure acts to force the water.

It will be very applicable for small manufacturers and amateurs, &c., who may require a cheap and simple engine, and one not likely to get out of order.

This arrangement of cylinder and valves does very well for a force pump, the water being drawn through the steam pipe and forced out at the eduction pipe: in this case it is proposed to make use of it as a garden engine, or a small fire engine.

The governor that is proposed to be used for this engine, the invention of Mr. Wilson, is shown in Fig. 3, Plate 13, and consists of a cast-iron or brass ball A, placed in the steam pipe B C, which at the governing point is tapered and curved upwards, as shown in the drawing, a stop being fixed at C to prevent the ball going so high in the pipe as to stick fast. The action of this governor is as follows: as the steam rushes along the pipe it carries the ball with it, which as it ascends, decreases the area that the steam has to rush through, and the higher it rises in the curve, the greater is this contraction, and the greater must be the pressure of the steam to counteract the force of gravity on the ball. The governor now exhibited has been applied to the ½ horse-power engine at the Oxford Works, and is found capable of regulating it so well, that when all the work is thrown off it will not allow the engine to run more than about 90 revolutions per minute.

Mr. Chellingworth exhibited one of the Engines of ½ horse power; also, the governor detached, to show the action. In answer

to a question, he stated that the cost of the engine exhibited was £10, and £18 complete with the boiler on wheels, as shown in the drawing.

The CHAIRMAN inquired whether the expense of working the engine had been tried?

Mr. WILSON said that the engine at the Oxford Works was supplied from the boiler of another engine, so that there was no means of ascertaining the consumption of fuel: the engine had been working constantly for six months, and had proved very useful and satisfactory.

Mr. E. A. COWPER observed, that he had seen the engine at work several times; it kept very fairly steam-tight, and he considered it would be usefully applicable to a great variety of purposes, on account of its being a very cheap construction and a good engine.

Mr. MIDDLETON thought the engine remarkably cheap, and a simple and convenient arrangement.

Mr. CHELLINGWORTH remarked that there were very few parts in the engine, only about a dozen separate pieces altogether. The engine was often worked very fast, from 150 to 200 revolutions per minute, and although so small, it was found very useful. It had drilled a number of $1\frac{1}{8}$ inch holes in a large cylinder cover, $1\frac{1}{4}$ inch thick, in $4\frac{1}{2}$ minutes each. The surface of the valve was found to wear quite even, and after it had been at work a short time it appeared burnished, and had remained so.

The CHAIRMAN said he thought it was a very ingenious and simple construction of engine; and though it did not admit of the economy of working the steam expansively, yet the whole consumption could be only so small, as to make that point of little consequence, and he thought it would be found very useful and economical in many applications. He proposed a vote of thanks to Mr. Chellingworth, which was passed.

A Paper, by Mr. Andrew J. Robertson, of London, was then read, being a continuation of his former Paper—On the Mathematical Principles of the Centrifugal Pump.

(The publication of this Paper has been unavoidably postponed.)

The meeting then terminated.

After the meeting a variety of specimens illustrative of a new mode of ornamenting the surface of metals, were exhibited by Mr. R. W. WINFIELD and Mr. R. F. STURGES, of Birmingham; the process of the ornamentation being very simple, and consisting in placing a sheet of perforated metal or paper, thread lace, net, &c., between the two plates of metal to be ornamented, and then passing the whole through a pair of ordinary rolls, such as are employed for rolling metal; this produces a very clear, sharp, and even deep impression of the pattern employed upon the sheets of metal which it is desired to ornament The depth of the indentation is such that the metal so ornamented can be subjected to the various operations of stamping, spinning, &c., for producing the manufactured article in its complete form, without any injury to the pattern; specimens of sheet steel were shown which had been ornamented with ordinary thread lace, and the delicate skeletons of leaves had left an impression on the surface of a copper-plate, from which engravings had been printed in the manner of the ordinary copper-plate printing, copies of which were exhibited.

Messrs. SALT and LLOYD, of Birmingham, also exhibited specimens of a new process for raising or stamping vessels, &c., formed from sheets of iron, tin, brass, &c., by which greater economy and rapidity are obtained than by the ordinary process. A heavy ram of 1¼ tons weight is raised by steam power a short distance of about a foot between guides, having the convex die attached to the under side of the ram, and the concave die or matrix is secured to the bottom of the frame as in ordinary stamping; the edges of the flat metal plate to be raised or stamped are then forcibly held down upon the matrix by a metal ring pressed down by eccentrics, whilst the blow is struck by the ram falling and driving the die through the ring into the matrix, which it fits accurately, the pressure of the ring on the edges of the metal plate being so adjusted as to allow the plate to draw uniformly into the required form without the edges becoming puckered; the metal is stamped cold.

PROCEEDINGS.

July 27, 1853.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, July 27, 1853, Samuel H. Blackwell, Esq., in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Ballot-papers were opened, and the following new Members were declared to be duly elected:—

MEMBERS.

Ralph Brown, Wednesbury.
Samuel Thomas Cooper, Leeds.
James J. Headly, Cambridge.
George Haden Hickman, Bilston.
Henry Maudslay, London.

The following Paper, by Mr. C. William Siemens, of London, was then read:—

ON AN IMPROVED GOVERNOR FOR STEAM ENGINES.

The governor of a steam engine has for its function to administer the supply of steam to the working cylinder in the ratio of the changeable load against the piston, the purpose of which is to obtain an uniform velocity in the engine. If it is the duty of the engine to impart motion to manufacturing machinery, the greatest possible regularity of motion is a desideratum of first importance, for it enables the manufacturer to work his machines at the

highest speed consistent with safety, and produce the largest quantity and a uniform quality of goods; it saves in personal attendance upon the machines; and, lastly, it increases the durability of the entire mechanism employed by preventing back-lashes and jerks.

The common (Watt's centrifugal) governor is notoriously imperfect in its action, being defective in principle in two respects.

1st—It cannot *regulate*, but only *moderates* the velocity of the engine; that is, it cannot prevent a permanent change in the velocity of the engine when a permanent change is made in the load upon the engine, and it can only *moderate* the extent of *permanent change in velocity*, because its influence upon the throttle valve depends on a change in the angular position of its weighted levers or pendulums, which change can only be effected by a permanent increase or decrease of the engine's velocity. And,

2nd—It cannot commence to act upon the valve until after the engine has undergone already a considerable change in its velocity, for at the instant when a portion of the duty is thrown on or off, the weighted levers are still in a state of equilibrium, and it is only by an accumulation of the fault, that they acquire a power to overcome the friction of the valve; to check the effect of the loss of time before the Governor begins to act on the engine, it then moves the valve to the opposite extreme, and a series of fluctuations will follow before the engine can recover a steady velocity.

Fig. 1, Plate 15, illustrates these defects in Watt's Governor. The dotted lines A A indicate the two extreme positions of the weighted levers in regular working, the one being at an angle of 25°, and the other of 35° from the axis. The corresponding extremes of velocity are inversely as $\sqrt{\cos. 25°}$ to $\sqrt{\cos. 35°}$, or as 905 to 952. The regular speed of the engine will, therefore, undergo a periodical change of $5\frac{1}{4}$ per cent. This is supposing that the pendulums are suspended from a point in the axis of rotation; but if, as is most frequently the case, they are suspended from points B B, removed some distance laterally from the axis, the change of speed will be nearly doubled, the length of pendulum being thus altered by the distance C C. The fluctuations which follow a sudden change of load will, however, far exceed those limits. Let

it be imagined that the engine is working at its medium speed, and that the Governor balls are revolving in equilibrium. Suppose a string to be tied between the two balls A A, of tensile strength equal to the resistance to the motion of the throttle valve. Let a portion of the load be thrown off the engine, and the velocity of its fly-wheel and of the Governor balls will gradually increase; but no alteration in the angular position of the balls can take place until their increase of centrifugal force suffices to break the string. The velocity will at this moment be proportionate to a much higher position of the levers than the adjustment of the valve D requires; they will, however, ascend into that position, and remain until the velocity of the engine has dropped sufficiently below its proper speed to accumulate acting power in the Governor in the opposite direction.

In practice, the defects of the Governor are ameliorated by personal attendance to the engine at such times when considerable changes in its load are expected to take place. In cotton and flour mills, for instance, the attendant on the engine is always forewarned of such changes by a bell, and effects the adjustment of the valve by hand.

Since the time of Watt, many attempts have been made to produce a more perfect Governor Amongst them the Governor of Hick is the most remarkable, the regulating power cf which depends on the rapidly increasing resistance, at increasing speeds, of the atmospheric air against rotating wings.

Fig. 2 and 3, Plate 16, is a diagram of this Governor. The two wings A A, are mounted upon a heavy boss B, containing a female screw, which is made to slide freely upon the threads of an upright male screw C; rotating motion being imparted to the latter by the engine, the wings will partake of the same until the resistance of the atmosphere against them equals the tendency of their entire weight to slide down upon the inclined threads of the screw. If the engine exceeds that velocity, the wings will rise and thereby shut the valve D, and *vice versa*.

It is apparent that it makes no difference to the speed of the wings, and consequently of the engine, whether the former are in

a more or less elevated position, and it follows, therefore, that this Governor is free from the first-named objection to Watt's Governor. It partakes, however, of the second, inasmuch as the resistance of the atmosphere is generally in equilibrium with the weight upon the inclined planes of the screw, and before either the one or the other can preponderate sufficiently to overcome the resistance of the throttle valve, it is necessary that the engine must have deviated sensibly from its regular speed.

Fig. 4, Plate 16, is another variety of Mr. Hick's Governor, which is remarkable for its simplicity and sensitiveness, although evidently less powerful than the former. The wings A A, are in this case made to revolve by the preponderance of one loose weight B, over another C, the engine being constantly at work on the shaft F to raise the heavier weight B, turning a second fixed pulley E; either of the loose weights is connected to the throttle-valve spindle D, so that the tendency of the heavier weight is to open the valve, while the engine is ever busy to close it.

Another variety of Hick's Governor was proposed a few years since, in which the wings themselves were shaped like portions of screws, and being free to slide upon straight keys on the driving shaft, were required to balance their weight by rotating under water, and so constantly tending to screw themselves upwards in the water.

The Pneumatic, or Cataract Governors, are a distinct group, of which a great variety have been proposed from time to time. The earliest is the cataract of the Cornish engine, by Watt. Heinrick's bellows Governor, Lariviere's and Pitchard's Hydraulic Governors, are other varieties, which, differing only in details, are represented by one diagram, Fig. 2, Plate 15. The pump A, is worked by the engine to force water or air below the weighted piston B, of a second cylinder or cataract, from whence it again escapes through a contracted aperture C, in a uniform stream. If the engine pumps more water than is discharged by that aperture, the weighted piston will rise and close the throttle valve D by the lever E; if, on the other hand, it pumps less than the discharge amounts to, the weighted piston will sink and open the valve Abstracting the differences in the height of water column above the discharge pipe,

and the friction of piston, the Hydraulic Governor would be capable of effecting the complete adjustment of the valve. It may moreover be made sufficiently sensitive for ordinary purposes by adopting a comparatively large supply pump. It is, however, very liable to derangement, owing to the valves and pistons employed, which, if they become leaky or stiff, will greatly affect the speed of the engine, and necessitate frequent re-adjustment of the discharge orifice, according to the judgment of the attendant.

Plate 17, represents the "Chronometric Governor," which is dissimilar in principle to any above referred to. It is the joint invention of the author's brother, Werner Siemens, and himself, and has been applied to a considerable number of engines since the year 1845.

Plate 18, shows a subsequent modification of the Chronometric Governor, having the advantage of greater simplicity and strength over the former: the latter it is the principal object of the present Paper to place before the Members.

The Original Chronometric Governor, Plate 17, consists of two essential parts, namely, the Chronometer A B, and the Differential motion C D E, between the chronometer and the engine, by which the effect upon the valve is produced.

The differential motion is obtained by means of three bevil wheels, one of which E, is turned by the engine, the opposite one C, by the chronometer in the opposite direction, and the remaining one D, is geared into both, and is at liberty not only to revolve upon its axis, but also to follow bodily the motion of either the first or second wheel by changing its angular position, and thereby the position of the valve.

The Chronometer is required to possess the following properties:—

1st.—To measure the time by a continuity of motion, unlike the vibrating pendulum, which, as it were, deals it out in periods of seconds or other units.

2ndly.—To possess considerable momentum, or instantaneous power to overcome resistance, in acting upon the valve.

3rdly.—To admit of great fluctuations in its maintaining power, without suffering its speed to alter; and

4thly.—To derive its maintaining power from the engine, and yet be affected uniformly by the same, in a similar manner as a clock derives its maintaining power from a falling weight.

The first and second conditions are fulfilled by a heavy conical pendulum A B, which, if freely suspended by a universal joint B, will complete one revolution in the time during which a vibrating pendulum of the same length would complete one double oscillation. The length of the conical pendulum must, however, be measured from the point of suspension perpendicularly to the plane A F, in which its centre of momentum rotates.

This length varies with the angle of rotation, and with it the time of completing one revolution in the inverse ratio of the square root of the length, or of the cosine of the angle of rotation.

It would be practically impossible to regulate the slight maintaining power required to such nicety that the pendulum would persist in a uniform angle, and, if restrained, its properties as a chronometer would be entirely sacrificed. A remedy, however, suggests itself, consisting in the application of a *break* I, which is put into action by the pendulum at the moment when it has reached its intended angular position; and, by absorbing the excess of maintaining power, beyond that sufficient to overcome the friction and resistance of the atmosphere, takes away its tendency to assume a still higher position. An undue depression of the pendulum is guarded against by having a greater maintaining power than would be absolutely necessary, the excess being continually absorbed by the break.

The maintaining power might be obtained by a falling weight acting by means of a cord upon a pulley, which might be attached to the wheel, moving in concert with a pendulum. By an arrangement similar to that of Mr. Hick's second Governor, the engine might be made to raise that weight again continually.

The differential motion, however, offers a facility for obtaining the desired effect, by simply attaching a weight H to a horizontal arm upon the spindle of a throttle valve; this weight, by its tendency to fall, pressing the moveable or differential wheel against the teeth

of the upper and lower wheels, exerts a constant power, tending to accelerate the pendulum; while the engine, by moving the remaining wheel in the opposite direction, produces the effect of constantly lifting the weight by the rod G.

It will be perceived that the Chronometric Governor fulfils the two conditions which are essential to obtain the perfect and instantaneous adjustment of the valve of an engine; namely, its speed is not in the least affected by the position of the valve (or the load upon the engine), and in distinction to all other known Governors, its action is simultaneous with the occurrence of a change in the load of the engine, its differential motion being indeed the most delicate test which could be applied to detect practically imperceptible irregularities in the speed of the engine. If a considerable portion of load were suddenly thrown off an engine, the fly-wheel would gradually acquire an increased velocity, but since only about 1-50th of a revolution in the advance of the uniform motion would suffice to shut the valve entirely, the adjustment of the same is effected before a sensible fault can occur. This result is corroborated by numerous experiments, the entire load of engines having frequently been thrown off without being perceived in the engine-house.

The Chronometric Governor has been applied to a considerable number of engines, where the difficulty of obtaining sufficient regularity was very great; such as flour mills, oil, and saw mills, &c.; in some cases it has now been at work night and day for upwards of seven years, and continues to give satisfaction; in others it has been less successful, for want of that degree of care and attention which delicate mechanism requires. Its principle has been put to the utmost test by the Astronomer Royal, who has applied it to regulate the motion of the great transit instrument at Liverpool (which is moved by water power), and to an instrument recording by touch, and it has obtained uniformity of motion within one or two seconds per hour.

The delicacy, and more particularly the expense of the Chronometric Governor, have been serious impediments to its more general introduction, and it is with a view to remove these that the

new arrangement, as shown in Plate 18, is proposed. The differential motion of this Governor is quite similar to that of the former arrangement, being only strengthened by the addition of a second differential wheel F. The principal change is in the Chronometer, which consists of a fly-wheel A A, in four segments, which are separately suspended from the lower bevil wheel at B B, and are closely surrounded by a cast-iron casing K K.

The weight H on the valve spindle will, on the engine being started, accelerate the wheel until the centrifugal force of its segments exceeds their gravity, and causes them to proceed outward. They will at that instant touch the casing K, and revolving at considerable velocity, the friction will readily absorb the excess of maintaining weight applied.

The principal feature of this Governor is its great power of action upon the valve, which renders it applicable to work variable expansion valves, or the floodgates of water wheels, without intervening secondary mechanism. At the instant when a change of load occurs, the power is indeed only limited by the strength of its rods and levers, because no amount of resistance could *suddenly* alter the velocity of its segmental fly-wheel.

It has further been ascertained by experiment, that this Governor will permanently support a weight of 1½ cwt. on the horizontal lever of the throttle valve: it possesses, moreover, the advantage of acting when placed in a slanting position, one having been placed, indeed, with its axis horizontally, instead of vertically, which continues to act well after several years' service; this Governor is thus rendered applicable to marine engines. Its great power would also enable it to act upon the lever of Woodcroft's screw propeller, with variable pitch, which it would regulate so as to maintain the engine at a uniform speed, independently of the speed of the vessel.

In the application of this Governor to engines, it is important to give it the sole and entire command over the admission of steam. For this purpose the throttle valve of the engine should be more perfect than those commonly applied. The valve shown in Plate 18 is preferred, inasmuch as its spindle is relieved from the pressure of the steam, which is made to enter from opposite sides

at I I. The connection between the Governor and the valve should, moreover, be made as direct as possible, and the maintaining weight be attached to the lever immediately upon the valve spindle, in order to prevent loss of motion.

Several Governors of the improved construction have been put up by Messrs. Hick and Son, of Bolton (one to an engine on their works,) and have proved practically successful during upwards of nine months of trial.

Mr. SIEMENS exhibited a working model of the improved Chronometric Governor, and explained its action: the drawing shown was about the size of a Governor suited to a 30-horse power engine, which would have a revolving weight of about one cwt.

Mr. SLATE thought the new Governor a very important and valuable addition to the steam engine, and that it completely removed the defects of the old Centrifugal Governor, which might be almost said to be the only imperfection left by Watt in the steam engine. He inquired whether any comparison had been observed of the breakage of threads that occurred in spinning machinery when the improved Governor was used in place of the old one, showing the comparative economy in manufacture produced by greater steadiness and uniformity of motion?

Mr. SIEMENS replied that the chief advantage was found to be in the increase of work done by the same machines, in consequence of the nearly absolute uniformity of motion enabling them to be driven at a higher speed. With the ordinary governor the fluctuation in speed could never be less than 5 per cent., and was practically considerably greater, and as the maximum speed had to be set at the limit allowed by the manufacture, the mean speed of the machines was consequently so much below; but the new governor allowed the maximum speed to be adopted constantly, as the motion was practically quite uniform, and no fluctuations were perceptible. There had been more experience of the results in flour mills at present than in cotton mills; and in those cases the new governor was found to do away with the constant attendance of spout-men, who are ordinarily required to regulate the speed of the stones by

hand, according to the variations in the quality of flour produced, depending on the speed, and the quality of the flour was found to be enhanced by the perfect uniformity practically attained in the speed; the quantity of work was very considerably increased by the certainty that the governor afforded of maintaining constantly the maximum speed required.

Mr. Slate inquired whether any difference had been observed in the deterioration and wear of the gearing, from the speed of the wheels being kept quite uniform?

Mr. Siemens replied, the new Governor had always the effect of entirely taking away the back-lash between the teeth of the wheels, by keeping all the machinery at an invariable speed; this must diminish the wear of the teeth, but it was difficult to obtain any correct return of the separate economy from this cause.

Mr. McConnell asked what was the time required for the correction of the velocity, when a large proportion of the load was suddenly thrown off, such as 3 or 4 pair of stones in a flour mill?

Mr. Siemens said the correction was almost instantaneous, even when the whole of the load was suddenly thrown off, as the engine could only make a very small portion of a revolution before the governor shut off the whole of the steam if necessary. He might mention in illustration a case where he was trying experiments on the efficiency of the governor with Mr. Field and other gentlemen, and the whole of the load of a 30-horse power engine was suddenly thrown off, and then put on again after some minutes, but Mr. Field, who was in the engine-house timing the engine, did not perceive any change in its speed.

Mr. McConnell observed it would be the perfection of the action of a governor to maintain the teeth of wheels always in contact on the driving side and prevent any back lash. The new form of the governor was a great improvement for practical application, though the use of four bevilled wheels instead of three gave a more complicated appearance than in the original form of the Governor. He inquired whether it was found to increase the wear and the difficulty of keeping in order?

Mr. Siemens said the new form of the governor was really as simple and not more expensive than Watt's Governor for the

same power of engine; the fourth differential wheel added very little to the expense, and removed the wear of the spindle, by balancing the pressure on both sides. Also, the governor itself never varies its velocity, so that there was no varying in the speed of the different parts, to cause unequal wear or strain, as was the case in the ordinary governor. The original form of the Chronometric Governor was more theoretically correct, but the small surface of the point of the spindle to receive all the pressure involved more care in oiling and keeping clean than could be depended upon from some of the rougher hands having the charge of engines; but in the cases where they were properly attended to, they had kept in perfect order during seven years' constant work, the spherical ball acquiring a fine polish. The present improved form of the governor was quite free from this difficulty; the friction segments were left entirely without oil, as the pressure was too small to cause injury from want of oil, and the use or absence of oil did not affect the correct action of the governor, so that no source of inaccuracy could arise from accidental want of attention.

The CHAIRMAN inquired whether the original governor was still employed by the Astronomer Royal to regulate the motion of astronomical instruments?

Mr. SIEMENS said that it continued in regular use for that purpose with entire satisfaction. It was peculiarly advantageous for the touch record instrument, consisting of a uniformly revolving drum, divided into minutes and seconds, on which the moments of observations were recorded by the touch of a pencil; the accuracy entirely depended on the absolute uniformity of the revolution of the drum, and this was previously liable to derangement from the variations in the resistance caused by variation in the pressure of the pencil, and the interval and time of its contact, but a perfect uniformity of motion was obtained by the action of the Chronometric Governor, by providing an excess of maintaining power above the maximum disturbance, the surplus being always absorbed by the friction of the break; with the transit instrument at Liverpool, the governor acted on the sluice of the small water wheel driving the moving apparatus, which amounted altogether to some tons weight.

Mr. C. Cowper inquired whether there was any means of altering the rate of speed of the engine if required, with the same governor?

Mr. Siemens thought it was not advisable to allow the means of altering the speed, as all machinery worked and kept in order best when it was maintained uniformly at the rate of speed for which it was calculated. But if necessary a change of speed could be readily obtained by employing a conical speed-pulley to drive the governor; the governor will always keep at the same absolute speed, but the engine may be set to run at any relative speed by proportioning accordingly the intermediate pulleys or gearing.

Mr. Clift inquired the effect of wear on the rubbing surfaces of the friction ring, whether they required renewal, and whether the wear affected the accuracy of adjustment of the governor?

Mr. Siemens explained that the only rubbing surfaces were the ends of the four steel pins, one in each of the segments; which were slightly rounded at the ends, with springs behind them to allow for wear; but the wear was exceedingly small, even in those of the first kind, which had been seven years at work, it was quite inconsiderable.

The Chairman asked how long the new form of Governor had been practically tried by regular work?

Mr. Siemens replied it had been in use about nine months.

Mr. Charles May said he had had the first form of Mr. Siemens' Governor in constant use for several years, with entire satisfaction; he was one of the earliest users of them, and had three in use at once, and he had never ceased to consider this governor as one of the greatest accessories to the steam engine. He thought it would be particularly useful in the iron districts, where the power required in driving the rolling mills and forge hammers was subject to such frequent and violent fluctuations; the rapidity of action of this governor was so great, that it might be said to adjust the throttle valve whilst the ordinary governor was thinking about moving. There were difficulties in some of the first applications of the governor, arising from prejudices, and particularly from defect of the throttle valves, which were often very inefficient; but he could bear testimony to its complete success

when properly applied. In one case of its application he had an engine of 50 indicated horse-power, sawing up 16-inch baulks into sleepers, where the work came on and off suddenly with the saw cut, but the engine making 35 strokes per minute did not vary anything like 1 stroke per minute, though with an ordinary governor there would probably have been a variation of 10 strokes per minute with the same work.

The CHAIRMAN expressed his opinion of the great practical utility of the new governor, and thought its application might be advantageously extended to the engines of iron works and steam boats.

A vote of thanks was passed to Mr. Siemens for his paper.

The following paper, by Mr. J. E. McConnell, of Wolverton, was then read:—

ON HOLLOW RAILWAY AXLES.

The subject of Railway Axles was brought before the Institution on a former occasion by the writer, when he gave the result of various experiments, showing the form and dimensions most economical of material, with a proportionate and proper strength of the several parts, and also the changes in the structure of the iron which appeared to have taken place from various causes during the course of working. Since that period the writer's attention has been constantly directed to the subject, and the opinion he then expressed respecting the fractures of axles arising from changes from the fibrous structure of the iron, to a brittle, short-grained, or crystalline condition, has been confirmed by repeated instances which have come under his knowledge.

With the view of improving the strength and durability of Railway Axles, the two most important points for insuring the safety and security of railway travelling, the writer, after repeated experiments, and obtaining all the experience and information he could collect on the subject, arrived at the conclusion that the hollow or tubular axle combined in itself, if properly manufactured, all the properties necessary to secure the best form for lightness, strength, uniformity of structure in the material, elasticity to neutralize the injurious effect of blows and concussions, and conse-

quent durability, from having a greater freedom from deteriorating effects.

The selection of the tubular form of axle originated from the knowledge, that with a considerably less weight of material in the form of the tube, a much greater strength can be obtained to resist torsion, deflection by pressure or weight, or concussion from blows. The resistance of a solid cylinder to deflection and torsion, increasing in proportion to the fourth power of the diameter (or the square of the square), but the weight increasing only as the square of the diameter, two solid cylinders, having the respective diameters of 4 and 5 inches, or 1 to $1\frac{1}{4}$, will have a proportionate weight of 16 to 25, or 1 to $1\frac{1}{2}$, but a resistanceof 256 to 625, or 1 to $2\frac{1}{2}$. Then if a hollow of $\frac{2}{3}$rds the diameter be made in the larger axle, its weight will be diminished $\frac{1}{2}$, ($\frac{2}{3} \times \frac{2}{3} = \frac{4}{9}$ or $\frac{1}{2}$ nearly,) and its resistance only 1-5th, ($\frac{2}{3} \times \frac{2}{3} \times \frac{2}{3} \times \frac{2}{3} = \frac{16}{81}$, or $\frac{1}{5}$ nearly), and the comparison with the smaller solid axle will then be 1 to $1\frac{1}{4}$ in diameter, 1 to $\frac{7}{8}$ in weight, and 1 to 2 in resistance, being double the resistance, with $\frac{1}{8}$th less weight.

The use of Hollow Axles was tried some years ago, but was not continued, the main objection being that there appeared a great difficulty of insuring, by the particular mode of manufacture adopted at that time, a sufficient uniformity of thickness of the sides of the tube throughout, and also of the soundness of material. The mode adopted consisted of rolling two or three bars of a semi circular cross section, which were welded together with butt joints, but with no internal pressure, and with solid ends where the bearings came. These axles, having no maundril or internal pressure during the process of welding, were found to be of a very uncertain strength throughout the axle, and the weakest point might be close to that part where the greatest force or strain would be exerted.

To overcome these objections, a mode of manufacturing Railway Axles has been introduced by the writer, which it is believed effectually accomplishes the objects in view, securing the utmost strength with the least possible amount of material, uniformity of structure of the iron, perfect equality of thickness of material, and soundness of manufacture.

The plan adopted is as follows:—A number of segmental bars of the best quality of iron are rolled to a section, as shown in Fig. 5, Plate 19, so as to form, when put together ready for welding, a complete cylinder Fig 6, about 1½ times the diameter of the axle when finished as Fig 7, the bars fitting correctly together, so as to have no interstices, and overlapping in such a manner as to insure a perfect and sound weld when completed, as shown in Fig 6.

This cylinder of loose segmental bars is temporarily held together by a screw clip, and each end being put into the furnace until a welding heat is produced, the bars are then partially welded together and the clip removed. The whole cylinder is then placed in the furnace, and brought to a proper welding heat; it is then passed through a series of rollers, BB, Figs. 1 and 2, Plate 19, which have each a maundril of an egg form, A, in the centre of the circular openings, which are attached and supported on the end of a fixed bar, the fixed bar being firmly secured at the opposite end, to resist the end pressure or strain during the process of rolling. The maundrils are made of cast-iron, chilled, fitting on like a socket on the end of the bar to a shoulder, and they are secured by a screw nut, so that they are easily removed when required.

The motion of the rolls is so arranged, by a reversing clutch on the shaft, that as soon as the axle cylinder has been drawn clear through, the motion is reversed, and the axle, which has been drawn on to the maundril rod, is again drawn back through the same opening in the rolls; it is immediately passed through the next smaller groove of the roll with a decreased size of maundril, and again reversed back through the same groove in a similar manner, and so on through a series of grooves in quick succession, each decreasing in size, and consequently increasing the compression and strength of the iron of which the axle is formed, and by the last groove it is passed through it is reduced to the proper diameter. At each time it is changed from one groove to another, the axle cylinder is turned by the workman a quarter round, so as to equalise the pressure on every part of its surface, to insure uniformity of the compression of the iron, and thoroughly complete a sound welding throughout every part of the axle.

The specimens before the meeting will show the soundness and

perfection of the manufacture, as a proof of which, in every test applied, either by blows on the outer surface, or by an immense splitting pressure, by driving a maundril in the interior, there has never been found in any one instance a failure of the weld, although the test has been applied to pieces cut off the extreme end, where it might be supposed the welding of the cylinder of the axle from various causes would not have so good a chance of being perfect.

The axle at this stage, after being welded and drawn down in the rolls to the size in Fig 3, is taken at once to a hammer, where it is planished between semi-circular swages over its entire surface. A small jet of water plays upon it during this process, which enables the workman to detect at once, by the inequality of colour, any unsoundness in the welding. From the hammer it is taken to the circular saws, where it is cut accurately to the length required, and ready to have the bearings formed upon it.

On coming from the hammer the axle is found to be perfectly clean both inside and outside, the scale being entirely removed. The ends are then re-heated, and gradually drawn down by a hammer to the proper dimensions and form of the journals, as in Fig. 4, a maundril being inserted in the end of the tube during the process of hammering.

The formation of the journals can also be produced by a rolling machine, constructed of tables the entire length of the axle, rolling transversely, each table being a duplicate of the other, and matrixes of the axle when finished. Or in another way, by two sets of rollers, each set consisting of three rollers running vertically, being of the same diameter, and driven at the same velocity, formed exactly to the shape of the bearing, and set the proper distance apart from shoulder to shoulder of the journals.

The manufacture of these axles has been entrusted to the Patent Shaft Company, and a great amount of credit is due to Mr. Walker, the managing partner of that firm, for the very excellent system he has adopted and carried out in the process of manufacture.

There can be no doubt that the Hollow Axles, as now manufactured, are much superior to any yet produced.

As an illustration of the saving in dead weight, take for instance a railway employing 15,000 waggons and carriages, and assume each of these vehicles to run on an average 10,000 miles per annum. The weight of two axles of the solid description finished, say 5cwt., and if replaced with Hollow Axles of equal strength, the weight per vehicle may be reduced $1\frac{1}{2}$cwt.; this taken over one mile of the above stock per annum will be 11,250,000 tons, and assuming the cost of traction for locomotive power at $\frac{1}{4}$d. per ton per mile, the saving will amount to £11,700 per annum, without taking into account the other advantages, and also the saving to the permanent way, &c.

In the samples of axles submitted to the meeting, two different kinds of bearings are shown, the parallel bearing with the rounded shoulder, Fig. 8, Plate 19, and also the double conical bearing, Fig. 9, such as is used on the Great Northern, Great Western, Bristol and Exeter, South Wales, and South Devon Railways. In either description of bearing the Hollow Axle is good, although it is believed that the conical bearing for *either* the Solid or Hollow Axle has a less tendency to injure the texture of the iron during the formation of the journal than the parallel shouldered axle, and it appears a matter well deserving the consideration of this Institution, to ascertain what, under all conditions, is the best form of axle bearing.

The following experiments, conducted by Mr. Marshall, the Secretary of the Institution, have been tried for the purpose of ascertaining the comparative strength of the hollow and solid axles to resist a transverse strain:—

Each axle was supported on massive cast-iron blocks, fixed at a distance of 4ft. 11in apart, to represent the support given by the rails to the axle A cast-iron block weighing 18cwt. was then let fall on the centre of the axle from a height of 12 feet, and the extent of bending was measured. The axle was then turned half round, and another similar blow given on the opposite side, bending it in the opposite direction. This proceeding was repeated until the axle was broken, and the particulars of the number of blows and amount of bending are given in the accompanying Table, No. 1.

The general results of these experiments are as follows:—

An *Old Solid Axle*, G, $3\frac{3}{4}$ inch diameter in centre, and $4\frac{1}{4}$ inch at ends, which had been at work three years, was bent $8\frac{3}{4}$ inches by the

1st blow; it was nearly straightened by the 2nd blow in the opposite direction, then bent 10 inches by the 3rd blow, and with the 6th blow it was broken in the centre square across.

A *New Solid Axle*, H, of the same dimensions, was bent 9¾ inches by the 1st blow, then nearly straightened by the 2nd blow, and bent 9½ inches by the 3rd blow, and by the 4th blow 2½ inches, and by the 5th blow it was broken ¾ inch from the centre.

The appearance of the fracture was crystalline over three fourths of the section, the remaining part tough fibre. This fracture is shown in Figs. 10 and 11, Plate 20.

A *New Hollow Axle*, I, 4⅝ inch diameter throughout, was bent 5 inches by the 1st blow, then nearly straightened by the 2nd blow, and bent again 5 inches by the 3rd blow. The 9th blow bent it 4½ inches, and the 10th blow 1⅜ inches. Up to the 15th blow it was bent alternately, the bends varying from 2 to 3½ inches. There was no appearance of failure or cracking, but a slight rising of the surface at the 15th blow. The blows were continued to the 27th, the bends varying from 2 to 3⅝ inches, and at this blow a fracture took place across the middle of the axle 1½ inches long. The 28th blow bent it ⅜ inch, and closed the fracture on the opposite side made by the preceding blow. By the 29th blow it was fractured two thirds through, and bent 9½ inches, the appearance of the fracture being very fibrous. This fracture is shown in Figs. 12 and 13.

A second series of experiments was made, to ascertain the comparative strength of the journals of the hollow and solid axles to resist breaking.

Each axle was supported on an anvil, with the inner shoulder of the journal projecting 1½ inches beyond the edge of the anvil, to represent the support of the axle in the nave of the wheel; 100 blows with 24lbs. sledge hammers were then struck upon the upper side of the outer end of the journal, the men being changed after striking each twelve or thirteen blows alternately. The amount of bending of the journal was then measured, and the axle turned half over, and another 100 blows similarly given on the opposite side of the journal; the same proceeding being then further repeated, and the several particulars are given in the accompanying Table, No. 2.

The general results of these experiments are as follows:—

An *Old Solid Axle* with 3 by 5 inch journals, that had been at work three years had one journal, C, broken off with 205 blows, and the other, B, with 53 blows: both fractures were square across the journal at the shoulder.

A *New Solid Axle*, F, with 3 by 6 inch journals, had the journal broken off with 570 blows, the fracture being irregular in form, and fibrous. This fracture is shown in Figs. 14 and 15, Plate 20.

A *New Hollow Axle*, D, with 3 by 5 inch journals, had 400 blows on the journal, which bent down the end $\frac{5}{8}$ inch, and produced a longitudinal split on the under side, $3\frac{3}{4}$ inches long, but no transverse fracture.

A *New Hollow Axle*, A, with the same size journals, received 800 blows on the end of the journal, which bent it down $\frac{1}{8}$ inch, and split the journal longitudinally on both sides, but caused only a slight transverse crack near the shoulder, $\frac{3}{4}$ inch long. The fracture is shown in Figs. 16 and 17.

The experiments on transverse strength, by a heavy weight falling on the centre of the axle, and giving the blow on opposite sides alternately, show that the hollow axle is nearly double the strength in that respect of the corresponding solid axle, the amount of bending being only 5 inches instead of $9\frac{3}{4}$ inches, and the number of blows required to break the hollow axle being 29, whilst the solid axle broke at the 5th blow, shows the hollow axle to be greatly stronger in resistance to fracture.

The hollow axle became $\frac{1}{8}$ inch oval in the centre after receiving the seventh blow, and it was only $\frac{1}{4}$ inch oval after receiving the twenty-eighth blow just before fracture; being bulged outwards $\frac{1}{16}$ inch at each side, and $\frac{1}{16}$ inch inwards at top and bottom from the original circular section.

The experiments on strength of journals show that instead of the journals breaking off square and short at the shoulder, as in the solid axles, the hollow axle journals stand a considerably greater number of blows, and then only split up longitudinally, instead of breaking off transversely, being a very important advantage in point of safety in working.

TABLE No. I.

Experiments on the Transverse Strength of Axles.

(Axle supported at each end, 4 ft. 11 in. length between supports, cast-iron weight of 18 cwt. falling on centre of axle, blows given on the opposite sides alternately.)

Description of Axle.	No. of Blows.	Height of Fall. Feet.	Deflection in centre from straight line. Inches.	Total Bending by each blow. Inches.	Remarks.
G	1	12	$8\frac{3}{4}$	$8\frac{3}{4}$	Crack on underside, 2 in. long, 1-16th in. open, an old flaw.
Old Solid Axle	2	10	$\frac{1}{2}$	$9\frac{1}{4}$	
$3\frac{3}{4}$ in. diam. centre	3	12	10	$10\frac{1}{2}$	
$4\frac{1}{4}$ in. diam. at ends	4	$11\frac{1}{2}$	—7	3	The supports gave way laterally, reducing the force of blow, Axle bent *upwards* 7 in.
	5	$11\frac{3}{4}$	$1\frac{3}{8}$	$8\frac{3}{8}$	Blow on same side as the last, four small cracks on underside.
	6	12	—	—	Axle broken square across, 3 in. from centre, surface of fracture crystalline.
H	1	12	$9\frac{3}{4}$	$9\frac{3}{4}$	
New Solid Axle	2	$11\frac{3}{4}$	$\frac{1}{4}$	10	
$3\frac{3}{4}$ in. diam. centre..	3	12	$9\frac{1}{2}$	$9\frac{3}{4}$	
$4\frac{5}{8}$ in. diam. at ends	4	10	$—2\frac{1}{8}$	7	Lifting chain broke at 10 ft. height, Axle bent *upwards* $2\frac{1}{8}$ in.
	5	12	—	—	Axle broken square across, $3\frac{1}{2}$ in. from centre, surface of fracture, 3-4ths crystalline, 1-4th tough fibre.
I	1	12	5	5	
New Hollow Axle ..	2	$11\frac{3}{4}$	$1\frac{3}{8}$	$6\frac{3}{8}$	
$4\frac{5}{8}$ in. diam. centre..	3	12	5	$6\frac{3}{8}$	
$4\frac{5}{8}$ in. diam. at ends	4	12	1	6	
	5	12	$4\frac{3}{4}$	$5\frac{3}{4}$	
	6	$11\frac{3}{4}$	$1\frac{1}{8}$	$5\frac{7}{8}$	
	7	12	$4\frac{1}{2}$	$5\frac{5}{8}$	
	8	$11\frac{3}{4}$	$1\frac{1}{8}$	$5\frac{5}{8}$	
	9	12	$4\frac{1}{2}$	$5\frac{5}{8}$	
	10	$11\frac{3}{4}$	$1\frac{3}{8}$	$5\frac{7}{8}$	
	11	12	$3\frac{1}{4}$	$4\frac{5}{8}$	
	12	12	$1\frac{7}{8}$	$5\frac{1}{8}$	
	13	12	$3\frac{1}{2}$	$5\frac{3}{8}$	
	14	12	2	$5\frac{1}{2}$	No appearance of failure or cracking.
	15	12	$3\frac{3}{8}$	$5\frac{3}{8}$	Very slight appearance of rising on the surface.
	16	12	$2\frac{1}{8}$	$5\frac{1}{2}$	No appearance of fracture on this side.
	17	12	$3\frac{1}{2}$	$5\frac{5}{8}$	
	18	12	2	$5\frac{1}{2}$	
	19	12	$3\frac{3}{8}$	$5\frac{3}{8}$	
	20	12	$2\frac{1}{4}$	$5\frac{5}{8}$	
	21	12	$3\frac{5}{8}$	$5\frac{7}{8}$	
	22	12	$2\frac{1}{8}$	$5\frac{3}{4}$	
	23	$10\frac{1}{2}$	3	$5\frac{1}{8}$	
	24	12	$2\frac{3}{4}$	$5\frac{3}{4}$	Some little appearance of rising on the surface.
	25	12	$3\frac{1}{8}$	$5\frac{7}{8}$	
	26	12	$2\frac{1}{8}$	$5\frac{1}{4}$	
	27	12	$3\frac{1}{4}$	$5\frac{3}{8}$	Fracture across centre of underside, $1\frac{1}{2}$ in. long.
	28	12	$3\frac{1}{8}$	$6\frac{3}{8}$	Closed the fracture on the opposite side.
	29	12	$9\frac{1}{2}$	$12\frac{5}{8}$	Axle broken 2 3rds through, split longitudinally 5 in., fracture very fibrous and irregular.

TABLE No. II.

Experiments on the Strength of Axle Journals.

(Axle supported at 1½ in. length from inner end of Journal, blows of 24 lb. sledge hammer on outer end of journal, each 100 blows given on opposite sides of the journal alternately.)

Description of Axle.	No. of Blows.	Total No. of Blows.	Deflection at end from straight line. Inches.	Remarks.
C				
Old Solid Axle	100	100	$\frac{1}{4}$	Small crack at Shoulder.
Been 3 years at work	100	200	$1\frac{5}{8}$	Crack 1 inch open at Shoulder.
Journal 3 × 5 in.....	5	205	—	Journal broken off square at Shoulder, surface of fracture fibrous, partly crystalline
B				
Old Solid Axle, ... the other journal of axle C.	53	53	—	Journal broken off square at Shoulder, surface of fracture all crystalline.
F				
New Solid Axle, ...	100	100	$\frac{1}{4}$	
Journal 3 × 6 in.	100	200	$\frac{1}{8}$	
	100	300	[illegible]	
	100	400	$\frac{3}{16}$	
	100	500	$\frac{1}{16}$	
	70	570		Journal broken off square at Shoulder, surface of fracture mostly fibrous.
D				
New Hollow Axle ..	100	100	—	
. Journal 3 × 5 in.	100	200	$\frac{1}{16}$	
	100	300	$\frac{3}{16}$	Longitudinal split 2¾ in. long, 5-16 in. open, on underside.
	100	400	$\frac{5}{8}$	Split underside 3¾ in. long, ⅛ in. open, no transverse fracture.
A				
New Hollow Axle ..	100	100	$\frac{1}{16}$	
Journal 3 × 5 in.	100	200	$\frac{1}{16}$	
	100	300	$\frac{3}{32}$	
	100	400	$\frac{1}{8}$	
	100	500	$\frac{5}{32}$	Split longitudinally 1 inch long.
	100	600	0	Cracked slightly obliquely.
	100	700	$\frac{1}{8}$	Split longitudinally 2½ in. long.
	100	800	$\frac{1}{8}$	Split longitudinally 4 in. long, small piece broken out at end, slight transverse crack at shoulder ⅜ in. long.

Mr. McConnell exhibited a number of specimens of the axles tried in the experiments, and specimens of the hollow axles cut in two longitudinally, showing the thickness of metal to be quite uniform throughout the axle and journals. He also showed and explained an instrument used for measuring accurately the thickness of the metal at the shoulder of each journal, and in the journal after the axle was turned; it consisted of a double sliding gauge (see Figs. 18 and 19, Plate 20), one sliding part AA being inserted into the open end of the axle, and shaped to fit closely to the inside of the shoulder at C, and the other sliding part B fitting the outside of the journal and axle; the whole gauge was held steady on the body of the axle by the arm and clip DD. When the gauge was adjusted by a compound sliding motion so as to fit the axle inside and out, the exact position of the outer sliding portion B was marked by bringing a screw stop E in contact with it, and it was then withdrawn sufficiently to allow the gauge to be disengaged from the axle by drawing the inner slide out of the axle; the outer slide B was then brought back to its former position by sliding it home to the screw stop, and the space thus left between the edges of the inner and outer slides A and B gave a correct outline of the thickness of the metal, which was traced at once on paper. Each axle was examined in this manner and registered before it was sent out to work, so as to provide against any axle being turned out in an imperfect state from the journal being accidentally cut into the metal too much at the shoulder.

The Chairman remarked, that in the fracture of the hollow axle all the iron appeared fibrous, but the fracture of the solid axles was mostly crystalline.

Mr. McConnell said he had found the same differences in all he had tried: the iron of the hollow axle was as fibrous throughout as the best bar iron.

Mr. W. Mathews inquired what was the saving in weight of the hollow axles, and whether they had yet been applied extensively?

Mr. McConnell replied the reduction in weight was about 2-5ths theoretically to obtain the same strength, but it had been taken at ⅓rd of the solid axles, to be on the safe side. The hollow

axles were being extensively applied on the North Western, Midland, and Great Northern Railways, and more than 500 had already been made; some had been at work for nine months with entire satisfaction.

Mr. W. MATHEWS asked what was the relative cost of the hollow axles, and whether any difference was found in the crystallising of the iron from the effects of working?

Mr. McCONNELL said that no observations could be made on that point yet, and it would be difficult to arrive at any conclusion upon it, except from actual long work.

Mr. NORRIS observed that in the fractures of the new solid axles there was considerable variation; some parts being fibrous and other parts crystalline. He said he had tried many old axles that had been 20 years at work on the Liverpool and Manchester Railway, and none of them appeared crystalline on breaking off the journals, though several new ones were found to break crystalline; the new ones were about ⅛ inch larger diameter in the journals. He doubted any crystallising effect being produced by working on the railway; he thought it depended more on the original manufacture.

Mr. SLATE remarked, that iron would be crystallised if overheated in the furnace, and the hollow axles might be injured in this way without proper care.

The CHAIRMAN said the most fibrous bar could be made crystalline in one part by overheating it.

Mr. CLIFT suggested that less heat might be required to weld the hollow axle than the solid one, on account of the reduced substance of the iron, which would be less injurious to it.

Mr. McCONNELL observed, that in the case of the sling chains for holding up in forging large bars, and in other similar instances, the continued concussion was found to have the effect of making the iron break in a certain time quite crystalline, though it had been quite fibrous originally; this was known to take place so regularly, that the time of breaking was reckoned upon, and they sometimes lasted only a few months. In the hollow axle there was a different condition of the iron from the solid axle, as in the latter the iron in the centre was not so solid as the outside, because the pressure

was only applied on the outside, and the larger the bar the more this was perceived; but in the process of manufacture of the new hollow axle, in consequence of the internal pressure combined with the external, and the small thickness of the metal, the whole axle was made as solid as the outside of an ordinary axle. It had, in fact, two skins, one outside and one inside.

Mr. SLATE remarked that the skin of iron was generally looked upon as stronger than the rest, but he doubted whether the skin was really of much importance to the strength, as it could only be a thin film of scale or oxide. He should like to see the experiment tried of a hollow axle bored out and turned so as to remove the skin, and expected it would be found to make little difference.

Mr. McCONNELL said the skin was important in cast iron, and the strength was considerably diminished if the skin was removed; he thought something of the same kind applied to wrought iron.

Mr. MAY hoped the experiment suggested would be tried; he thought the ordinary idea of the skin was a delusion, both in cast and wrought iron, and he believed there would even be found more strength per square inch in the area left if the skin were planed or turned off.

Mr. DUCLOS observed, that in cast iron the skin would be different in composition, assimilating to steel, and harder than the rest of the metal, if not stronger, according as it was more or less chilled, but in wrought iron the skin was mainly oxide of iron, and was really weaker than the pure iron.

Mr. SLATE thought a cast-iron bar planed down ⅛th inch on each side would prove quite as strong per square inch as before.

Mr. JAMES NASMYTH said he had tried a careful experiment on that very point; he cast some bars 2¼ inches square, and planed some of them down on each side to 2 inches square, and he found that these were 10 per cent. weaker for the proportionate transverse breaking strength. These bars were green sand castings, and consequently partially chilled; loam castings would not probably show the same effect; he considered the effect of chilling was to increase the strength.

Mr. SLATE said he had made a somewhat similar trial, though not so careful an experiment, and he did not perceive any difference in the strength of the skin.

Mr. May observed, that $\frac{1}{8}$th inch on every side might be too much to remove for ascertaining the relative strength of the skin alone, as the interior of a large bar was not so strong. It had been ascertained by the experiments of the Government Commissioners, that a cast-iron bar three inches square was only $\frac{2}{3}$rds the proportionate strength of a bar one inch square, as the centre of the bar became less solid in cooling; consequently, a bar one inch square, cut out of the centre of a three inch bar, would be considerably weaker than a bar cast one inch square, and not from the circumstance of the skin being removed, but from the iron being less solid; if only about $\frac{1}{16}$th inch were planed off a bar, it would remove the skin, but he thought the strength would be found not to be injured.

Mr. J. Nasmyth considered the skin effect extended more than $\frac{1}{8}$th inch deep, at least the chilling was perceptible so far.

Mr. G. England remarked, that if the less dense part of a solid axle at the centre were taken out by boring, the axle would not be proportionately diminished in strength; and this was in effect done in the hollow axle, with the additional advantage of the internal pressure, making the iron as sound throughout as in a thin bar, and considerably sounder and stronger than it could be in a large bar or shaft.

The Chairman said it was certainly much easier to make a bar 1 inch thick, of good quality and fibrous throughout, than one 3 or $3\frac{1}{2}$ inches thick; and in effect the hollow axle was a bar less than an inch thick throughout, in place of the ordinary solid axle, $3\frac{1}{2}$ or 4 inches thick.

Mr. McConnell thought it had to be defined what was meant by the term skin; in forging any bar it became denser gradually at the surface, and consequently stronger, the effect penetrating to a greater or less depth, according to the circumstances, and it was that he referred to, not a mere film on the surface.

Mr. Slate remarked, that in reference to the crystallisation produced in iron by concussion, he thought the effect did not take place unless the strain was beyond the elastic limit more than five or six tons per inch, so as to cause a permanent change in the arrangement of the particles of the iron. He had tried an experi-

ment in connection with Mr. Wild, in which a weight was suspended by a bar an inch square, and was lifted up and down eighty times per minute by an eccentric worked by a steam engine, constantly, night and day; this was continued for a length of time that was supposed equivalent to the effect of twenty-five years' work, but no change or crystallisation in the iron was perceived.

Mr. McConnell observed, that whatever was the nature of the strain, and the change produced by concussion, the effect of the continued blows and concussion to which a railway axle was subjected, must be greatly diminished when the axle had a large hollow through the centre, instead of being entirely solid, as the effect of a blow on one side would be mostly lost in the vacant space of the centre, instead of being all communicated through the mass of the axle. He showed specimens of a hollow and a solid axle, which had been run hot for two hours without oil in a lathe, at a speed corresponding to about 20 miles an hour travelling: the solid journal broke off with 179 blows quite short and crystalline, but the hollow journal would not break transversely, and split longitudinally in several places with 400 blows, and did not appear injured.

Mr. Adams said he thought the conical journals were preferable to the ordinary cylindrical ones, and they were particularly adapted to the manufacture of the hollow axles, by avoiding the sudden shoulder. He had found the conical journals less liable to heat than the others when well fitted; in the cylindrical journals, as square shoulders were found preferable in practice to shoulders much rounded, it was important to maintain a uniform strength of metal at the shoulder.

The Chairman observed, that the subject of railway axles was of great importance for safety and economical working, and the new hollow axle appeared to be a valuable and successful improvement. He proposed a vote of thanks to Mr. McConnell for his communication, which was passed.

The following Paper, by Mr R. S. Norris, of Warrington, was then read :—

IMPROVED RAILWAY JOINT CHAIR.

In bringing before the Institution a plan for a new kind of Joint Chair for Railways, it will be unnecessary to expatiate on the advantages of a *firm joint*, as regards economy of maintenance of the road and rolling stock, and safety.

The object of this Paper is to describe a method which has been in use on a crowded part of the London and North-Western Railway for above eighteen months, during which time it has stood well, and is now being extensively used on the same line.

The plan is to cast a chair or coupling on the rails at the joints as they lie in the line, by means of chills and a portable cupola. The hot metal flowing freely into the chill is allowed to come in close contact with the rails, and in cooling contracts so as to grip the ends of the rails firmly together. The great object to be attained is the converting of the rail into a continuous girder, which shall not deflect at the joint more than at any other part; every successive year's experience having forced the attention of engineers and others to this point, to attain which many plans have been tried with more or less success.

Whatever mode of joint is adopted, or whatever method of joining the ends of rails, it is necessary that a certain allowance should be made for the longitudinal motion caused by the expansion and contraction of the rail. This object is attained, wherever necessary, by putting the chills, previously heated, on the ends of the rails for a short time, until they become hot, when they are taken off and a thin wash of loam and blacking is laid upon the rail end, which instantly dries on, and when the melted iron is poured against it absolute contact with the rail is prevented. Although provision is thus made for the expansive and contractile force of the rail, the cavity in the Chair being parallel to the rail, clips it sufficiently tight to prevent any vertical or lateral motion of the rails; the amount of surface of contact between the rail and chair is about 100 square inches, being 50 square inches to each rail end.

This great surface prevents any perceptible wear taking place on the rail ends from the longitudinal motion of expansion; and as no motion can take place vertically or laterally, no shock can take place by the action of the wheels, so that the joint will remain good for years, which has been confirmed by practice, so far as it has gone.

The operation of casting is very simple, and is performed without hindering the passing of trains during the execution of the work.

The apparatus consists of chills and a portable cupola, and the process is as follows, when operating on a line already laid :—Each joint sleeper or block is first lowered by the platelayers about three inches, so as to give room for the application of the chills, or is removed altogether for the time, and the old chair being taken off the joint, the chills are applied, shown in side elevation in Fig. 10, Plate 21, in Plan, Fig. 2, and in Section, Fig. 3, consisting of a bed-plate A, with two lips, one on each side, holding down the side chills B and C, which slide in the grooves; these are put to the rail and held together by the screw clips E E, forming a mould for casting the chair. This operation is quickly performed, and the chill is then packed under temporarily with loose metal plates; the moment this is done a train may pass over it without hindrance.

The two steel pins D D are then put in their places in the chills, and form, when in their places, the cores for the holes of the holding down spikes. The chill mould being thus fastened in its place, is ready for the melted metal, which is run into it at the lip F, until it is level with the top of the sides at G, which is a large open space as shown on the Plan, Fig. 2, at G, and by allowing such an ample space for the escape of air, this prevents all possibility of blowing.

The chills are made to fit the rails by a projection at each end, H H, which grips the rail firmly, and a little loam is applied on the outside, to prevent the hot metal making its way out of the chill mould.

After a lapse of about five minutes the mould is taken off, which is done in an instant, leaving the Chair as shown in Fig. 4, and

end elevation, Fig. 5. The form of this Chair is such as to make it a strong and rigid clip, closely fitting the two ends of the rail along its whole length. Chairs may by this method be cast of any form. When the Chair is cold enough, the sleeper or block is replaced, and the Chair spiked to it.

The operation is the same in relaying new roads, only that the expense of lowering or removing the block or sleeper is saved.

The metal used up to the present time has consisted of old chairs, mixed with a little new iron. This is melted in a portable cupola, shown in elevation, Fig. 8, Plate 22, and plan, Fig. 9; it is formed of a cylinder A A, of sheet iron 1-16th of an inch thick, 2 feet 3 inches in diameter, and 4 feet 6 inches high, lined with fire bricks and clay B B, in the usual manner, 4 inches thick.

The cupola weighs about 6 cwt., and is easily lifted by the workmen on to a platelayer's lorry, and taken to the place required, when it is lifted off and placed on a few sleepers laid on the slope of a cutting or embankment. When once so placed it will serve for half a mile of road without moving again, as the metal is so hot as to enable its being taken in a moulder's ladle on a lorry to the chills at a quarter of a mile on each side the cupola

The cupola has a belt or air chamber at C C, into which passes the air from the fan, and it has four tuyeres of two inches orifice to admit the air to the fire. The fan D consists of a chamber 1 foot 10 inches inside diameter, and 9 inches wide, and weighs about 3 cwt.; it is detached from the cupola by drawing out the nozzle from the entrance to the air belt, and can then be lifted separately into its place. The fan is either turned by hand winches E E, or when the operations are extensive, by a small steam engine, Figs. 10 and 11, weighing about 10 cwt., and can be lifted by eight men, and placed on and off a lorry and on to the slope, in the same manner as the cupola.

The yield of metal from so small a cupola is very great: as much as 3½ tons has been run down in seven hours by two men turning the handles of the fan, and nearly 4½ tons by the use of the engine in the same time.

A smaller cupola, weighing about 2 cwt., is used for repairs of the line.

A good fastening is made for middle chairs by taking out the wooden key from the common middle chair, and casting an iron one in its place, as shown in Fig. 6. This is done by heaping dry sand round the Chair, as it stands in its place at I I, and then running metal into the cavity so formed, coloured red in the drawing, leaving a lip projecting over the Chair at K K; only a few of these have yet been put down, but they have stood the test of two years' working over without failure, and are still tight. In casting, the hot metal running into the Chair expands it, and its contracting upon the cast key in cooling makes it tight.

It may be remarked, that the new Chair occupies exactly the same position on the sleepers, and has the same fixing as the common Joint Chair, so that in case of damage to the line from accident or slips, it can be repaired quickly in the ordinary manner, by using the old Chairs and wood keys until the small cupola can be brought to bear.

Mr. Norris exhibited specimens of the Chairs and the cast-iron Mould, complete; also a specimen of one of the new Joint Chairs from the North Union Railway, which had been laid down for eighteen months in a line of great traffic, where 500,000 wheels had passed over it during the time; the two rail ends were cut off, and remained fixed fast in the chair, and the surface of the joint was level and smooth, although the rail ends had been much indented at the time the chair was cast on, from the rails having been recently turned.

The Chairman inquired what length of line had been tried with the new chairs, and how long they had been at work?

Mr. Norris replied, that five miles had been recently laid with these chairs near Rugby, and about a mile was previously laid near Crewe, and elsewhere, which had mostly been at work one and a half years.

Mr. Woodhouse said the recent trial of the chairs near Rugby had been made under his superintendence, and he had found the

result highly satisfactory. It had been intended to relay that portion of the line during the present summer, but the new Joint Chairs had proved of such benefit, that they would probably give several years additional life to that road. He consequently recommended the adoption of the plan on a considerable length at other parts of the line, which was now in progress.

The CHAIRMAN asked what difference was felt in the trains running over the joints on the portion that had been altered at Rugby?

Mr. WOODHOUSE said the joints could not be felt at all with the new chairs; there was no comparison of the ease in travelling over the old plan of joints.

The CHAIRMAN asked what was the usual time required for the process of casting the chairs?

Mr. WOODHOUSE replied that the average of the work done at Rugby was about one chair cast every four minutes, including the whole process of preparation.

Mr. SLATE remarked it was certainly a very ingenious process of casting the chairs, and must make a thoroughly firm joint; he inquired what was the expense of casting?

Mr NORRIS said that the labour of casting cost about sixpence per chair, and the cost was about a shilling per chair, including all expenses except the metal, which weighed about 50lbs. The expense of casting was much diminished as the men got more experienced in managing it. At first they could only cast 40 chairs per day, but the rapidity of casting increased with practice to 80 per day, and now 120 per day were cast by common platelayers, who had never before had anything to do with melted iron.

Mr. SLATE said he had seen the first of these chairs 1½ years since, and had then an unfavourable opinion of their standing in work, from the great contraction of the melted metal in cooling on the rigid rail; but it appeared that the wrought-iron rail was expanded by the heat of the melted metal sufficiently to make the chair safe by its contraction again in cooling. He thought the new chair made a very perfect coupling of the rail ends, and was a great improvement on fishings and other plans, which he could only regard as make-shifts; and though they had a very good effect compared with the previous

plan of having nothing to couple the rails together at the joints, they were still far removed from perfection. The new chair might be said to be quite perfect, if it could be made quite fast on the rail without allowing it to slide.

Mr. Norris observed that only every third or fourth joint was made a slip-joint for expansion; he was aware what a great advantage it would be to have no slip-joints, and by no means maintained that to be impracticable; the expansion of the rails successively by the heat of casting the chairs on, would perhaps elongate them sufficiently to make provision for the expansion from the highest temperature they would be afterwards exposed to, and the tension would then resist the contraction from cold.

Mr. May remarked, that Mr. Brunel had now many miles length of Barlow's rail on the South Wales Railway, all riveted fast together, without any provision for expansion, and no difficulty was experienced in consequence. There was some misconception on this point, respecting the action of expansion; it was limited in amount of force, and if opposed by a greater force no amount of expansion or contraction could take place. Wrought-iron raised in temperature 15° was expanded $\frac{1}{10000}$th of its length, and exerted a force of one ton per square inch of section by the expansion; consequently, no expansion of the rails would take place if a resistance were opposed of one ton per square inch for each 15° rise of temperature. He thought it probable, that Mr. Norris's plan ultimately would require to have no expansion joints to perfect it, and in many cases he did not doubt the plan being an excellent one.

Mr. James Nasmyth said he had witnessed the whole process of casting the chairs, and fitting on the iron moulds, and considered it a very successful plan, and of the utmost value and importance to the durability of the line as well as to the safety of the public. The trains ran full speed over the red-hot chairs directly after they were cast. He thought the slight tortuosities of all roads, even in the straight parts, would be probably found sufficient to allow for the effect of expansion, without making any provision of slip joints.

Mr. May suggested that an experiment could readily be tried to ascertain the actual amount of expansion of the rails, by having a number of thin graduated wedges, to be dropped into the joints at

the hottest part of the day and at night, to measure the amount of expansion over a considerable length of rail. It would probably be found to be very insignificant, as the ordinary chairs offer a considerable resistance to a longitudinal motion of the rail, by the hold of the keys on the rail, the chairs on the keys, and the ground on the sleepers; though of course the resistance in Barlow's rail was a different case, where the rail, chair, and sleeper were all one.

Mr. Woodhouse remarked, that in laying the rails the men place small wooden or iron packing pieces 1-16th of an inch thick between the rail ends at the joints, to make the ordinary allowance for expansion, and they always find that if these pieces are put in early in the day they become so tight in the middle of the day that they cannot be got out, but are quite loose in the cool of the evening.

The Chairman observed, there was no doubt the expansive action of the heat would always produce its full effect, either by compressing the iron of the rails, or producing some motion or distortion in their position.

Mr. Norris said that cases had occurred of the road becoming hog-backed, rising with the sleepers out of the ballast, from the want of sufficient allowance for expansion, also in curves the rails and sleepers had been pushed bodily outwards in the ballast by the effect of expansion. The extreme change of length in this country, from 80° or 90° variations of temperature, amounted to a yard per mile, and this yard length must be disposed of somewhere in each mile, either by sliding or tension, or else by bending upwards or laterally, if there was not less resistance to compression of the iron.

Mr. C. Cowper remarked, that the extreme change of temperature of 90° would cause a total strain on the iron of 6 tons per square inch, at 1 ton for 15°, which amounted to the very severe total force of 40 or 50 tons on the whole sectional area of the rail of 7 or 8 square inches, to overcome any supposed resistance.

Mr. May thought the change of temperature in the rails would be considerably less than that of the air, because they were partly buried in the ground, and must therefore follow the temperature of the surface of the earth, which fluctuated much less than that of the air.

Mr. Duclos remarked, that the expansion or contraction of the rails would only take place from the mean temperature to the maximum or minimum, and as the mean temperature of the air in this country was about 50°, and the maximum 90°, making a change in the air of 40°, the actual change in the rails from the mean temperature was probably less than 30°, causing a strain of not more than 2 tons per inch expansion or contraction.

The Chairman observed, it was an important subject for consideration, whether the allowance for expansion could be entirely dispensed with; and the new Chair appeared an important step in that direction, and might lead to doing away with longitudinal bearings.

Mr. Norris said that his attention had been first directed to the subject of this Chair about two years since, by the circumstance of a very extensive alteration having been in contemplation from the ordinary rail and cross sleepers to a bridge rail on longitudinal timbers, the alteration being proposed entirely on the ground of obtaining a superior coupling of the joints with the longitudinal bearing, than the ordinary rail and chair. But he objected to the bridge rail and longitudinal timbers as more expensive: and the idea then occurred to him of running the melted metal into the chairs to fill them up solid, and make a rigid coupling of the joint; and this led him to casting the joint chairs solid upon the rails in their places, as the complete way of carrying out the object.

Mr. Woodhouse remarked that the process of casting the Chairs would be going on for some time near Weedon and Leighton, on the London and North-Western Railway, and he should be glad to show it to any Member who might wish to see the process.

A vote of thanks was then passed to Mr. Norris for his Paper.

The meeting then adjourned.

PROCEEDINGS.

OCTOBER 26, 1853.

The GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, October 26th, 1853; CHARLES BEYER, Esq, Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The following Members were put in nomination for the election of Council and Officers of the Institution at the next Annual Meeting. when the President, Vice-Presidents, and five of the Council in rotation would go out of office, according to the rules of the Institution.

PRESIDENT.

WILLIAM FAIRBAIRN, .	Manchester.

VICE-PRESIDENTS.

(Six of the number to be elected.)

SAMUEL H. BLACKWELL,	Dudley.
WILLIAM BUCKLE, .	London,
EDWARD JONES, . .	Liverpool.
RICHARD PEACOCK, . .	Manchester.
*JOHN PENN, . . .	London.
JOHN RAMSBOTTOM, . .	Manchester.
*ARCHIBALD SLATE, . .	Dudley.
ROBERT STEPHENSON, M.P.,	London.
*JOSEPH WHITWORTH, .	Manchester.

COUNCIL.

(Five of the number to be elected.)

*CHARLES BEYER, . .	Manchester.
*WILLIAM BUCKLE, . .	London.
JAMES FENTON, . .	Leeds.
BENJAMIN GOODFELLOW, .	Hyde.
*EDWARD HUMPHRYS, .	London.
*EDWARD JONES, . .	Liverpool.
JAMES KENNEDY, . .	Liverpool.
SAMPSON LLOYD, . .	Wednesbury.
*JAMES E. MCCONNELL, .	Wolverton.
WILLIAM MATHEWS, .	Birmingham.
*WILLIAM A. MATTHEWS, .	Sheffield.
EDWARD SLAUGHTER, .	Bristol.

TREASURER.

*CHARLES GEACH, M.P., .	Birmingham.

SECRETARY.

*WILLIAM P. MARSHALL, .	Birmingham.

*(The Officers for the present year are marked thus *)*

The following paper, by Mr. William S. Garland, of Soho, Birmingham, was then read :—

DESCRIPTION OF THE NEW PUMPING ENGINES AT THE BIRMINGHAM WATER WORKS.

The subject of the present paper is a description of a pair of pumping engines, manufactured by Messrs. James Watt and Co., of Soho, for the Birmingham Water Works Company; and the intention of the author has been more to place before this Institution a record of well and successfully executed works, rather than to claim any particnlar novelty in their construction.

These Water Works were established in the year 1830, and the Company then erected two engines, having cylinders of 61 inches diameter, and 8 feet stroke, each working two pumps of 18 inches and 20 inches diameter, and of 6 feet and 8 feet stroke respectively to the lower levels of the town, or working one pump only when raising water to the upper reservoir. These engines were found of sufficient power for the necessary supply until the year 1850, at which time the demand had so much increased that the Company determined, at the recommendation of Mr. Rofe, their engineer, to augment their establishment by the addition of two new engines of greater power than the old ones.

The cylinders of these engines are of 72 inches diameter and 10 feet stroke, working a pump of 23 inches diameter, also of 10 feet stroke, under a head of 252 feet, which with the bends in the main and friction is equal to a total resistance of 285 feet, and to a load upon the plunger of 124 lbs. per square inch, or upon the steam piston of 13 lbs. per square inch. The weight upon the plunger required to overcome the load upon the air pump, the friction of the engine, and to maintain a velocity of 10 strokes per minute, is nearly 26½ tons, which is equal to 142 lbs. per square inch upon the area of the 23 inch plunger, and 14½ lbs. upon the piston; the power therefore of each engine when making 10 strokes per minute is equal to 180 horses; and the total power which the Company now have for supplying the borough is equal to 530 horses.

Fig. 1, Plate 23, shows a general elevation of one of the engines, and Fig. 2, Plate 24, is a plan showing both the engines. The cylin-

ders AA have steam cases, and are enclosed in a covering of felt, having an outside casing of wood, BB, (as shown upon a larger scale in Fig. 3, Plate 25,) to prevent the radiation of heat, and the top of the cylinder and upper nozzle are covered in a similar manner.

Fig. 3 shows a vertical section of the cylinder, with its piston and rod, and side section of the nozzles. Fig. 4 is a front section of the nozzles, showing the steam-valve C, equilibrium-valve D, and exhaustion-valve E. These valves (shown to a larger scale in Fig. 5, are 13, 15, and 18 inches diameter respectively, and of the double-beat construction, by which the principal part of the pressure that the common conical valve is subject to is removed. The steam governor valve F is made of the single conical form, (there being no necessity for making this valve upon the double-beat principle,) and it is regulated by a screw and wheel handle.

The load upon these engines is a variable one, to the extent of the difference of the dead level of the upper reservoir and the amount of friction of the water *in transitu*, and it sometimes happens that the water is being drawn off faster than the engine supplies it, and the velocity of the water beyond where the great draught occurs is consequently decreased, and the resistance proportionably diminished.

To prevent any accident to the engine by going out too suddenly, in consequence of this diminished resistance, a throttle-valve G is placed between the upper and lower nozzle, and in the pipe communicating with the top and bottom of the cylinder, which is regulated in its opening by a screw and wheel handle in a similar manner to the steam governor or throttle-valve, and by thus contracting the passage, or in other words, wire-drawing the equilibrium, the equalization of pressure between the top and bottom of the cylinder is more slowly formed, during the time the plunger is descending, to the extent the weight is in excess of the diminished resistance. In these engines this valve has been found of invaluable service, and it will even hold the plunger at the top of the stroke. It acts exactly like putting on a break to a crane when lowering a weight, without absorbing any power or causing any disturbance to the working of the engines. The piston is represented in Fig. 3 as descending, or what is technically called making its in-door stroke, and the steam and exhaustion-valves are open, and the equilibrium-valve closed.

In Fig. 4 the steam governor valve F and the equilibrium governor valve G are represented as wide open.

The opening of the steam, injection, and exhaustion-valves is regulated by a cataract, and the speed of the engine is thus under the control of the engine-man. The equilibrium-valve is opened by quadrant catches, and is dependent upon the closing of the exhaustion-valve, the former being opened upon the closing of the latter, and is shut in the usual manner by a tappet upon the plug-rod.

The injection-valve is also made upon the double-beat principle, to render the strain upon the exhaustion-valve spindle as little as possible, by relieving it of all unnecessary pressure, the underside of it being open to the condenser.

In the event of the bursting of any pipe in the main, and the resistance to the plunger being suddenly removed, a detent is fixed upon the plug-rod, to prevent the repetition of a blow upon the spring beams by the catch pins. This detent comes into action upon the engine making more than its usual length of working stroke, by holding the steam-handle down, and thus preventing the opening of the steam valve. This adjunct to the hand gear, though it may never be brought into operation from such an occurrence, would evidently be of great value in such a case.

In Figs. 1 and 2 is shown the air-pump H and condenser I; the former is of 34 inches diameter and 5 feet stroke, and the latter is of similar capacity. The air-pump bucket is fitted with a brass annular or ring valve, and the delivery and foot valves are of the usual construction, or what are termed flap valves. A vacuum is obtained varying from 27 to 29 inches, according to the state of the atmosphere.

Each engine has its separate condenser cistern, formed of cast-iron, which is supplied by a cold-water pump of 13½ inches diameter and making 5 feet stroke.

The feed-pump W is of 6½ inches diameter, and 2 feet 6 inches stroke, fitted with an air-vessel, shown in Figs. 1 and 2.

The main pump, with its suction and delivery pipes and air vessel, is shown in Figs. 1 and 2, and a section to a larger scale is given in Fig. 7, Plate 26. The plunger K, as before stated, is 23 inches diameter, and of the same length of stroke as the steam piston, viz., 10

feet. The suction-valves LL, and delivery-valves MM, (shown enlarged in Fig. 6,) are of the double-beat kind, and fitted in pairs for the purpose of giving additional security to the action of the pump in the event of one of them sticking or becoming otherwise deranged. They are of cast-iron, and their beating faces are composed of a mixture of tin and lead, which is run into a dovetail recess turned in the cast-iron seat, and thereby becomes perfectly fixed. The water-way through these valves is of the same area as the plunger, and the lift of them is about 2 inches, the blow when shutting being scarcely perceptible. These valves were taken out after 6 months' work, and the beating faces of them were found to be as perfect as when they were first put in.

The air vessel N is 7 feet internal diameter and 18 feet high, or 15 feet high above the delivery branch into the main, and it is replenished with air by a separate pump O, of 6 inches diameter and 3 feet 6 inches stroke, shown in Figs. 1, 2, and 7. An air-cock P is fixed upon the suction pipe of this pump, by which the necessary quantity of air to be supplied is regulated. This cock only requires to be partially open, and when closed entirely, the pump lifts water only.

The air-vessel is of great importance, as by its equalizing action the motion of water in the mains is rendered continuous, and a less weight in consequence is required to give the necessary velocity to the descent of the plunger in the out-door stroke. At the top of the pump-plunger is fixed the pole case, containing the necessary weights to overcome the load or resistance, and, as before stated, is equal with the plunger and rod to about 26½ tons.

Upon the first delivery pipe joining the air-vessel is fixed a safety discharge-valve Q, Fig. 2, of 6 inches diameter, loaded by a lever and weight a little above the pressure upon the main, to prevent any undue force being thrown upon the pump from the accidental shutting of the sluice cocks between the engines and the town.

The main lever or working-beam RR, Fig. 1, is 30 feet long, cast in 2 plates, each of 3 inches in thickness, and the depth of it in the middle is 6 feet, and at the ends 2½ feet. Each of the plummer blocks has saddles of cast-iron between them and the wooden spring beams SS, which latter are 30 inches deep and 20 inches wide, of the best

Memel timber, and formed of 6 pieces in section, bolted and bound together with wrought-iron straps. These beams are carried by the lever wall T, and by the end walls of the house.

The catch-pins UU are of wrought-iron. The parallel motions VV are of the usual kind, which require no further explanation than what is shown in the drawing of the general elevation of the engines.

It may be interesting to state, that the quantity of water lifted by every stroke of each engine is equal to 180 gallons, or 1800 gallons per minute, and 108,000 gallons per hour, weighing upwards of 483 tons lifted in each hour.

Mr. Garland explained the drawings of the engine and pump, and stated that the first engine was started in July, 1852, and the 2nd in April, 1853.

Mr. Cowper inquired whether it had been found requisite to have double valves to the pumps from any accidents having happened, as there would be the disadvantage of an additional load on the piston to lift the extra valves, which would probably amount to 1 lb. per square inch? He thought the area of the valves was large and supposed the object was to diminish the height of their lift.

Mr. Garland said no difficulty had been experienced with the valves; the double valves were only adopted as a measure of precaution, for obtaining additional security to the action of the pump working under such a heavy pressure.

Mr. Ramsbottom asked what pressure of steam was employed, and whether it was worked expansively?

Mr. Garland said that the pressure of steam was 12 lbs. per square inch, and it was cut off at $\frac{1}{3}$rd of the stroke, expanding through $\frac{2}{3}$rds.

Mr. Ramsbottom observed, that as there was a constant weight on the plunger to force the water, and the steam was employed only to lift that weight, there appeared no provision for variation in the resistance to be overcome.

Mr. Garland replied, that the load on the engine was constant, except the variation in friction of the water in the mains, according to the level at which the greatest discharge of water happened to be tak-

ing place, the water being always forced against the head of the upper reservoir at the highest part of the town, which was 252 feet above the engine. The only difference made would be in the speed of the engine; the usual speed was 10 strokes per minute, equal to 200 feet per minute average speed of the steam piston and the pump plunger. The actual pressure of water on the pump, 124 lbs. per square inch, as named in the paper, was measured by a Bourdon's gauge, fixed in the engine-house; and there was found to be very little fluctuation in the pressure, the variation rarely amounting to 5 lbs. per inch.

Mr. Ramsbottom inquired what duty had been obtained by the engines, from the coal consumed?

Mr. Garland said that the actual duty had not been ascertained, because the only fuel used was Staffordshire coal-slack; and as its evaporative value compared with the best Welch coal (which was invariably used in testing the duty of a pumping engine) was not known, there had been no opportunity of obtaining a definite result as to duty.

Mr. Cowper remarked, that the steam pressure was small as compared with the Cornish pumping engines, and he considered that a higher pressure would be more economical. He thought the pump appeared large for keeping the air-vessel supplied with air, and inquired whether it had been found necessary?

Mr. Garland said the pipes from this pump were found to get hot if sufficient water was not pumped with the air, from the quantity of heat liberated from the air under so great a compression, which was otherwise carried off by the water mixed with the air; and there was no objection in having the pump large, as the extra power for working it was spent usefully in pumping water.

Mr. Ramsbottom asked whether any experiments had been tried to ascertain the proportion of air absorbed by the water, as it was an opportunity from which some interesting results might be obtained?

Mr. Garland replied that the experiment had not been tried, but the quantity of air absorbed was certainly considerable in amount under that pressure.

The Chairman inquired about the construction and working of the pump-valves and valve-seats?

Mr. Garland said the valves were cast-iron, with faces and seats of a composition of tin and lead run into a dove-tailed groove, which was

found to be just the right degree of softness, and appeared to stand better than any other material.

Mr. Cowper thought that composition was certainly the best for the purpose; wood faces had been originally used by Harvey and West in their double-beat valves, but the valves were now much improved by using the tin and lead faces, which adjusted themselves accurately in work, and were very durable. He thought the form of valve shown in the drawings was originally due to Mr. Slate.

Mr. Garland said he believed that form of valve was originally designed by Mr. Slate.

Mr. Cowper remarked, that he thought it was preferable to make a pumping engine double-acting, on the bucket and plunger plan, with the plunger half the area of the bucket, so as to pump half the water in the up-stroke and half in the down-stroke, enabling an engine and pump of half the size to do the same work; also to add a crank and fly-wheel, and work at a higher speed, which further reduced the size and cost of engine and pump. In one instance that he knew, there were four 150 horse power engines on this plan working very satisfactorily, from 12½ to 21 strokes per minute, with 7 feet length of stroke. But he considered the horizontal engine with direct-acting pump and crank, was the most advantageous and economical when the water to be pumped was near the engine-house floor.

The Chairman observed that it was an important subject, and the paper read was of much interest, from its practical nature: it was important for the Institution to obtain such papers, as accurate descriptions of machinery that had been executed and worked successfully. He proposed a vote of thanks to Mr. Garland for his paper, which was passed.

The following paper, by Mr. Robert Waddell, of Liverpool, was then read:—

ON AN ESCAPE WATER-VALVE, AND A GOVERNOR FOR MARINE STEAM ENGINES.

The horizontal engine has of late years become a favourite engine in the British Navy, for the screw steam ships have the advantage of being better protected from shot than the vertical engine, as the horizontal engine can be placed in the ship entirely under the water line; the boilers are also kept as much under the water line as possible, for the same purpose. All boilers are liable to prime, more or less, but when they are confined in the height of steam room, they are more apt to do so, as in this case, and carry a considerable portion of water from the boilers into the cylinders along with the steam.

Water in the cylinders has, no doubt, been the cause of more accidents to engines than anything else, and many cases occur of the bottoms of cylinders being forced out, pistons broken, piston-rods bent, and side-levers broken,—all from the effects of water in the cylinder.

This can easily be accounted for, from the great power the one engine has over the other when water accumulates in the cylinder; the two engines being connected together in right angles, if a few inches of water has got into one cylinder, which will prevent the piston from getting to the end of its stroke, the opposite engine will be near half-stroke, at which point it gives out the greatest power, as the piston and crank are travelling near the same velocity, while the piston of the first engine, from the position of the crank, is nearly at a stand; then the power of the second engine, exerted to compress the water, will be in proportion to the difference of velocity of the two pistons, plus the momentum of the engine. The fly-wheel of the land engine acts on it in the same way when the engine is turning its centre.

Escape water valves have been applied on cylinders to take off the water, to prevent accidents taking place from the accumulation of water in them, but with little success. The fault of the ordi-

nary escape water-valve is its being loaded like a safety-valve, so that no water can leave the cylinder till the piston forces it out, and then the strain is very severe, from the small area that the water has to pass through, which causes the damage to the engine.

The object of the improved Escape-Valve, described in the present paper, is to draw the water off the cylinder throughout the stroke, and not allow it to accumulate, as with the ordinary escape-valves, till the piston strikes the water. The construction of the valve is shown in Plate 27. Fig. 1 is a horizontal cylinder, with an escape water-valve attached to each end, to the flange G, shown separately in Fig. 2. B is a small cylinder attached at G; F is a float inside the cylinder, a spindle passes through the float, and is attached to it. A and C are two conical valves nearly in equilibrium, attached to the spindle with nuts at top and bottom of the cylinder; the top valve A is made like a piston on the under side, so that when it leaves its seat it will prevent a great rush of steam from passing. It is also made slightly larger than the lower valve C, so that the pressure of steam will assist in raising the valves, and a small accumulation of water about the float will open the valves; that is, suppose the float, valves, and spindle weigh 50 lbs. for the largest size of engine, and the pressure of steam in the boilers not to exceed 15 lbs. per square inch, and the top valve to be 3 inches more area than the bottom; then there will be 3 times 15=45 lbs. excess of pressure on the upper valve, being within a few pounds of raising the valves, without any water about the float. The float should be made with sufficient buoyancy to raise the valves when there is no pressure of steam to assist.

It will be seen from the construction that when water enters the small cylinder from the steam cylinder, the float is buoyed up, opening the valves and allowing the water to escape through the bottom of the small cylinder. There is a hole in the spindle to carry off any water that might collect in the float.

The top valve is made larger than the bottom one to answer two purposes, namely, for the pressure of the steam to assist in raising them when a small quantity of water comes about the float; and, secondly, when a vacuum is formed in the cylinder the valves are

kept shut by the atmospheric pressure being greater on the top valve than the bottom one; this will be the case if a great quantity of water enters the steam cylinder, the valves will then be kept open running it off, until the exhaust takes place.

The drawings show an escape-valve suited to a 400-horse power engine, with 93-inch steam cylinder; the escape-valves will then be about 6 inches diameter, and the float about 13 inches; this will give the float sufficient buoyancy to rise and open the valves before it is entirely covered with water, besides the assistance of the differential steam pressure on the valves.

A Marine Engine Governor to check the admission of steam when the engine runs away from the water, leaving the wheels or screw, is much required. The ordinary governor has been tried for the purpose, but was found not to answer, as its action is too slow in shutting-off and letting-on steam; also the pitching and rolling of the ship in a heavy sea is very much against its action, and from these defects it has been abandoned.

The ordinary method that is adopted at present, when the engines are racing in a heavy sea, from the water leaving the wheels or the screw, is for the engineer either to close the throttle-valve to the required extent, to prevent the racing, or stand by the engines, with the throttle-valve handle in his hand, watching the motion of the engines, to shut off the steam when the engine runs off, and let it on when the wheels take hold of the water. In a voyage across the Atlantic this has often to be done for several days, night and day; because closing the throttle-valve, and allowing the engines to go all the time throttled, when the wheels are in the water as well as out, diminishes the speed of the ship to a great extent. When the wheels leave the water, the steam that passes into the cylinders is lost, as the engines have nothing to absorb their power, besides the liability to break down the engines if they are allowed to race to any extent.

The Governor described in the present paper can be used equally as well on land engines as on marine, where the work they are doing is not of a steady nature, such as driving a rolling-mill or a saw-mill, &c. When the saws leave the log, or the iron leaves

the rolls, the engine has nothing to absorb the power, and will run off before the ordinary governor will shut-off sufficient steam, its action being too slow for such sudden changes.

The proposed Governor is shown in Figs. 3 and 4, Plate 27, applied to the steam-pipe to act upon the ordinary throttle-valve, or a separate valve may be fitted for it. A A is the steam-pipe, and B the throttle-valve; C is a small cylinder fitted with a piston and rod, and bolted to the steam-pipe; the ends of the cylinder are connected to the steam-pipe by two pipes, one above and the other below the throttle-valve. When the engine runs away, in consequence of the diminished resistance of the water, from the wheels or screw being out of the water, the pressure of the steam is also diminished by being wire-drawn by the throttle-valve; consequently, on the upper side of the piston, we have the pressure the same as in the boilers, and on the under side the diminished pressure due to the sudden expansion of the steam, in flowing into the cylinders. The effect is to depress the piston C, and shut-off the steam from the engines, by partially closing the throttle-valve; but when the pressure becomes equal, or nearly so, on both sides, the piston is raised, and the valve opened by the spiral spring S. The stops H on the lower end of the piston-rod can be adjusted by set screws, to allow the throttle-valve to be opened and closed to the required amount.

It will be seen by examining the Governor, that when the throttle-valve is closed, it will remain so if time is not allowed for the space between the valve of the engine and the throttle-valve to get filled to the same pressure as above the valve, so that an equilibrium of pressure may take place on the piston, then the spring will open the valve; if the throttle-valve opens too soon, the stop H must be altered, to allow the throttle-valve to close further, so that the space between the throttle-valve and the engine-valve will take longer to fill, and the reverse if it opens too soon.

A working model of the escape water-valve was exhibited; and the Secretary explained that the author had been prevented from attending the meeting, having just started for America in the steamer of which he was the engineer.

The CHAIRMAN observed, that the governor appeared capable of more general application, and suitable for iron works as well as marine engines.

Mr. COWPER thought the governor might prevent many accidents in iron works from carelessness of enginemen leaving their engines, by checking the increase of speed in the case of a sudden diminution of load on the engine.

Mr. BENJAMIN GIBBONS said that the common governor was found sufficient for this purpose, as power was absorbed by the very large mass of matter in motion in the heavy fly-wheels and gearing, which prevented any sudden change of velocity from taking place. The proposed governor would certainly act very sensitively, and was an ingenious and simple contrivance.

The CHAIRMAN observed that the water-valve would be an improvement on the ordinary escape-valve, from its constantly drawing off the water, and preventing any accumulation in the cylinder.

Mr. GIBBONS thought the escape water-valve a good plan for horizontal cylinders, such as marine screw engines, but it was not suitable for vertical cylinders, which were mostly in use.

Mr. CLIFT inquired what provision was usually made in vertical cylinders for the escape of the water?

Mr. GIBBONS said there was no provision made for its escape, except flowing through the ordinary steam-ports along with the steam, at the top and bottom of the cylinder.

Mr. RAMSBOTTOM said he had known much trouble to be caused with vertical cylinders by the accumulation of water, from the want of provision for carrying it off. The proposed escape-valve appeared likely to be advantageous in the case of horizontal cylinders, by preventing the accumulation of water; but in vertical cylinders it could only act fully at the lower end, as the water at the upper end could not be drained off except at the moment of the piston arriving at the top of its stroke.

Mr. COWPER thought there would be an objection to the application of the escape-valve, from air being drawn in a little at each stroke, because there must be some interval of time during the closing of the valve by descent of the float; and although assisted by an excess of pressure downwards, from the top valve being a little larger area than

the bottom one, the closing could not be instantaneous; and at every eduction stroke, air would be drawn in a little through the water at the bottom valve, as well as through the leakage of the upper valve.

The CHAIRMAN said they would be glad to have the results of practical trials of the governor and escape-valve; and proposed a vote of thanks to Mr. Waddell, which was passed.

The following paper, by Mr. John Ramsbottom, of Manchester, was then read :—

DESCRIPTION OF AN IMPROVED COKING CRANE FOR SUPPLYING LOCOMOTIVE ENGINES.

This Coking Crane was designed by the writer about two years ago, in consequence of the great wear and tear of coke skips used for coking engines, at the Manchester Station of the London and North-Western Railway, and the necessity that then more particularly existed fo coking the engines in the least possible time, owing to the limited space there was then for the traffic. The crane is shown in Plate 28, and consists essentially of a large wheel or circular rim 20 feet in diameter, made of iron segments A A A (see plan, Fig. 2) having arms B B B, 20 in number, which may be considered the jibs of so many small cranes. These are mounted upon one common post or pillar CC, which revolves upon bearings at top and bottom, and each arm or jib is tied by a rod DD, to a hollow cast-iron cone, which is fastened upon the top of the pillar, and is adjusted by means of a screw and nuts. In fact, the whole may be considered, so to speak, as twenty small cranes working from one common centre. Around the circumference of the rim are suspended, at equal distances, twenty wrought-iron cylindrical buckets, E E E, 2 feet 6 inches diameter, and 2 feet 8 inches deep. Each bucket is fitted with a bow handle and swivels, so as to be readily turned over when its load is to be discharged. The segments A A A are also provided with teeth upon the lower edge, which gear into a pinion G, and the movement is carried forward to the handle H by means of the two pairs of bevil wheels, and in such proportion as to give 115 revolutions of the handle for one of the crane. The chief peculiarity, however, consists in the main post being fixed in an inclined

position. This is done to such an extent as to throw one side of the rim 6 feet higher than the other, and it will be seen from the drawing that the buckets on one side are sufficiently low to be filled direct from the waggon L, and on the other sufficiently high to deliver their loads upon the tender M. The buckets hold in the aggregate 3 tons of coke, so that the crane will carry, ready for delivery at a moment's notice, sufficient coke to supply three passenger or two goods engines at least. Of course, when the crane is fully loaded, the whole is in equilibrium, and it can then be moved by a force sufficient to overcome the friction only; on the other hand, the greatest power is required when the buckets are empty on the descending side, and full on the other. The proportion given, however, will enable one man to work it under the worst circumstances.

In using this crane, the practice is to keep the buckets full as far as circumstances will allow, and any engine requiring coke has the tender backed under the higher edge of the crane; the cokeman then turns the crane round by the handle previously described, and continues to do so until the fireman or other person has turned over as many buckets of coke as are required. The time rarely exceeds two minutes for the delivery of 21 cwt. of coke, and is often less.

As respects the saving of labour, it may be mentioned that four men were formerly required to deliver coke at this station, and it is now delivered by two, and the skips are dispensed with.

The fact that this little machine has worked very satisfactorily during the last two years, has induced the writer to bring it before this meeting; it evidently possesses the advantage of carrying a considerable quantity of coke ready for immediate delivery, and of elevating, advancing, discharging, returning, and lowering the buckets by one simple movement.

There is one slight drawback, however, namely, that an engine cannot run past it, owing to the chimney; but where this is considered necessary, the crane may readily be fixed about 3 feet further from the rails, and the coke delivered by a moveable shoot.

The Chairman observed, that he had seen the coking crane described in the paper, and thought it a very simple and efficient plan; the one objection that had been named, of not leaving space for passing along the line by the side of the crane, might probably be remedied in several ways if required in another situation.

Mr. Ramsbottom said that object had not been thought of at all in the present case, as it was at the termination of the line, where it could not be extended beyond the crane, and that was the only one on the plan at present tried. The crane had been found very convenient for use, as it required very little power to work it, and held a large store of coke always ready for loading the tenders; it had been in constant work for more than two years, with scarcely any expense for repairs.

Mr. Cowper thought the crane was well contrived for the purpose, and suggested that it might readily be made applicable to a situation where a clear passage was required on the line past the crane, by omitting a portion of the buckets on one side, perhaps one-third, which would always allow the passage of a train, when the blank side was turned towards the line; the same quantity of coke might be carried by increasing the size of the buckets or the diameter of the crane. He thought that a perfect coking crane should, if possible, be balanced in all positions, for the engineman to be able to pull it round by hand, and take in a supply of coke without requiring a second man to help; on the same principle as the present large 8-inch water cranes, which supplied the water with great rapidity without help. This might be accomplished by working the crane round on a level instead of inclined, so as to be always balanced, and lifting the coke up previously to the level by other means.

Mr. Woodhouse thought there would be a difficulty in raising the coke by other means, and the oblique crane which he had frequently seen at work was a very convenient mode of gradually raising the coke by the same movement as changing the buckets. In some places the coke was raised up at once from the waggons to a high platform, and then loaded into the tenders by a shoot; but that plan was not so convenient for measuring the coke as the crane with buckets holding exactly 3 cwt. each.

Mr. Ramsbottom observed that the average height the coke had to be lifted in loading the tenders was only 3 feet, as the coke was already

lifted an average of 3 feet, or half the total height 6 feet, in the process of filling the buckets all round.

Mr. Cowper suggested that each bucket when loaded on the platform might be slung up or raised by a small windlass, and then hooked on to the crane at the upper level.

Mr. Ramsbottom observed, it would certainly store up more power ready for coking the tenders, if all the coke were previously lifted up to the full height 6 feet, instead of an average of only half the height; but the simplicity of the machine would be somewhat interfered with.

Mr. Downing remarked that there might be room to pass the crane by fixing it a little farther from the line, and tipping the buckets over the side of the tender; there being no necesity he supposed to empty over the centre of the tender.

Mr. Lloyd suggested an octagon form for the purpose instead of a circle; he thought the same plan of crane would suit well for filling blast furnaces, where, as in Wales, there was not more than 6 feet to lift the materials in many cases.

Mr. Gibbons thought the plan might be very applicable in several parts of iron works, such as raising small coal and rubbish, and removing the cinder from the furnaces; he thought it a very good contrivance, involving the least possible expenditure of labour, where a large quantity of material was required to be lifted a small height.

A vote of thanks was passed to Mr. Ramsbottom for his paper.

The following paper, by Mr. Samuel Lloyd, jun., of Wednesbury, was then read :—

ON AN IMPROVED TURN TABLE.

In the construction of Turn Tables three leading principles have been followed; either the bearing has been on the centre only, with no bearings at the circumference, or with bearings at the circumference and none at the centre; or a combination of these two modes has been adopted by allowing the weight to rest in part upon the centre, and in part upon the bearings or rollers at the circumference; this last construction has been most frequently adopted. Most of the turn tables first laid down on railways were made to rest on fixed rollers, as Fig. 1, Plate 29, for the sake of economy; but although fixed roller turn tables are the cheapest kind in first cost, and were much used on the first railways made, live roller tables have been generally adopted latterly, from the greater ease with which they turn;—as in the fixed roller turn table the weight bears on the axle of the roller, producing rubbing friction, but in the live roller table it bears upon the circumference of the roller, producing only a rolling action without any rubbing friction, except in the guiding ring. Some fixed roller turn tables have however of late been constructed, with much larger rollers than those formerly used, which has the effect of perceptibly lessening the friction; but these tables seldom continue long in good working order, in consequence of the rollers *indenting* the top table. This is an objection to which all roller turn tables are subject, but those with fixed rollers most especially, from the top table always resting upon the rollers in these, in the same position, thus receiving the pressure always on the same points; and as the amount of surface in contact between them is very small, (see Fig, 2,) the whole amount of surface in contact between the surface of the rollers and the top table being not more than three square inches, as shown, if so much, the rollers soon wound the under surface of the top table, so that the latter becomes indented over every roller. As soon as this takes place, considerably more power has to be exerted to turn carriages upon them, as the resistance to be overcome is greatly increased by the whole weight having to be lifted out of each of the hollows formed from the above cause.

But in addition to the increase of friction occasioned by these indentations, they cause also great unsteadiness, making the table rock, and thus clatter and hammer against the rollers as each pair of wheels passes on and off its two opposite sides. This deteriorating action goes on to a greater or less extent in almost all roller tables, often occasioning the top to break, if it is not very strongly made; this rocking is often greatly increased, and occasionally entirely originates, from the centre pin being too tightly screwed down, so as to take the weight entirely off the rollers on one side of the table.

This defect has led to the construction of turn tables with a centre pin that acts merely as a centre guide, without taking any weight. Turn tables of this class, if made with radiating rollers, have the advantage of remaining very solid for a time after they are put in, but frequently this is not of long continuance, for all roller turn tables are unsteady, if the rollers are not *all* correctly turned to the same diameter, and cottered or screwed up exactly to the same distance from the centre; each roller being a portion of a cone, its outside diameter is greater than its inside, and if either of the rollers is screwed up too tightly, the table rides on it. This is sometimes occasioned after a few months' wear, by the pressure of the table top continually exerting a force tending to drive the rollers upon which it rests outwards, which is sure to be the effect if either of the nuts that screw them up becomes slack. This pressure tending to force the rollers off the roller-path, causes considerable friction against the guide ring at the boss of every roller, and is one cause of the heaviness with which even live roller turn tables work, causing railway labourers in goods stations, whenever they have the chance, to wrench them round by horse-power.

In an improved construction of roller turn tables extensively adopted, the weight of the table top is nearly counterbalanced by a weighted lever, which constantly tends to lift the centre pin without actually doing so, making the table much easier to turn, by diminishing proportionately the pressure on the rollers; the rollers also are not fixed as in common turn tables, but in an inclined position, as shown in Fig. 3, with their upper surfaces level, for the purpose of preventing the level of the table top from being disturbed by the surge of carriages passing over. In some turn tables the rollers have been made with rounded edges, as in Fig. 4, and level roller-paths, with the view of,

lessening the friction of turning, and increasing the steadiness of the table by resting it on a plane instead of a cone; but these rollers have not been found to be durable, and the roller-path becomes worn hollow by them. A more successful plan for diminishing the friction has been the use of spherical balls instead of rollers, (shown in Fig. 5,) travelling round in a live ring, to prevent the balls from rolling off, but allowing them room to shift their position on the roller-path as they move round, which prevents them from wearing the roller-path into grooves; and as the balls travel in a circle, sometimes in one direction and sometimes in the contrary direction, they continually present a fresh portion of their surface for the bearing, which preserves them from being worn unequally.

There is one objection to these tables, but which applies still more strongly to roller turn tables, namely, the extreme difficulty of turning them in frosty weather, when the dirt on the rollers and roller-paths becomes frozen; horse-power is then often required to stir them, or a fire has to be lighted to thaw the congealed mud collected on them.

Centre bearing turn tables are practically free from this objection, and also from the one before referred to, namely, the bearing surface becoming indented, from the small extent of surface in contact with the rollers. A turn table of this class is shown in Figs. 6 and 7, Plate 89, of which many are in use. In these the whole weight is carried by the centre pivot or ball; any side pressure resulting from the weight to be turned not being balanced exactly upon the centre, being carried by the two sets of horizontal rollers A A that travel with the top table round the centre pillar B B, and are fixed to the jacket C C.

This description of turn table has two important advantages;—Great *ease in turning* and smoothness of motion, and great *durability*, numbers of them having continued in use for many years without requiring any repairs. The ease with which they turn is owing to the great leverage obtained by the power being applied at the circumference of the table, and to the resistance being confined to the centre ball and the rollers round the centre pillar, instead of being at the circumference as in roller tables, in which it acts at nearly as great a leverage as the power. So that while no leverage is obtained when the power is applied in turning a carriage at the outer edge of a roller table, a leverage of 14 to 1 is gained in a centre bearing turn table,

constructed as shown in Figs. 6 and 7, even if half the resistance be supposed to take place at the horizontal rollers, and only half at the centre pin.

Centre bearing turn tables as usually constructed have most of them two defects; namely, great extra cost of foundations, and unsteadiness and liability to deflect; the last being the most serious defect, which renders them objectionable for any situation where much traffic is likely to pass over them. Their deflection upon trains passing over them being caused by the whole of the weight of each carriage acting at a great leverage to strain the working parts of the table while running on and off. To meet this defect, a number of supplementary rollers have usually been fixed at the circumference, (see D D, Fig. 6,) for the purpose of catching the weight and preventing any undue deflection when the weight is passing on and off the edge of the table, these rollers being fixed a little below the level of the table top, so as not to touch the top and come into action until the top gives way by deflection, or by canting on one side. This plan has however the objection of being unmechanical, as it implies a certain degree of failure in the machine before it can come into full operation.

The *unsteadiness* of the centre bearing turn tables described above may be considered as the principal cause of their disuse, notwithstanding their superiority over roller tables in ease of turning; another cause being the expense and depth of the foundations requisite. The object of the present paper is to describe an improved plan of construction, that will remove these defects.

A Turn Table upon the improved plan is shown in Figs. 8 and 9, Plate 30; the action of which is as follows:—The centre pillar, A, is fixed on a block of stone or other suitable foundation, within which is fixed a toggle-joint or other lever, BB, which is connected with the centre pin C as shown: by means of this the turn table is raised when wanted for use, the lever then assuming the position shown by the dotted lines D D. The drawing shows the table not in use, the weight at such times being all carried on the outer ring EE, at the periphery of the table, and none upon the centre pin. By this means the table is made quite steady and solid, and not likely to be injured by trains passing over it; whereas, as soon as the centre pin or pivot is made to rise by means of the lever B assuming the position shown by the dot-

ted lines D D, which is worked into this position by means of a rod connecting it with another lever or toggle-joint F, forming one of the catches of the table, the turn table top is raised off the outer ring and may be turned with great facility, the weight then resting entirely on the centre pin or pivot BC.

Provision is made, as in other centre bearing tables, for the weight of the table not being equally poised on the centre, by horizontal rollers GG, which carry the side pressure, and serve by their contact with the centre pillar A to preserve the turn table in a level position while rising and while in use. When the turn table is no longer required it is again made solid by the handle M of the lever F, which forms one of the catches, being lowered into its original position.

Figs. 10 and 11 show another mode of construction, by which the same result is obtained of supporting the table top by its circumference when out of use, and upon its centre when in use. The action of the lever BB in this table is merely to raise the table sufficiently to disengage the blocks H H. When the table is not in use the lever is in the position shown at BB, but as soon as it is necessary to turn a carriage, the table top is eased off the four blocks H H at the circumference, under the main line rails, by being raised from $\frac{1}{4}$ to $\frac{3}{8}$ths of an inch by the action of the knuckle-joint lever F; by this time the stud I. which is fixed upon the long lever BB, having traversed to the end of the slot in which it works, carries the rod K with it, thus withdrawing the four blocks H H from under the outer ring E E. The long lever is now at the position shown in the drawing, or at the bottom of its stroke; the centre joint of the knuckle-joint lever F has now passed from one side of the centre line of the table to the other. The table top is exactly at the same level when the long lever is at the bottom of its throw as when it is at its top; the difference being that when the long lever is up as shown by the dotted lines DD, the table top is supported entirely at its circumference on the four blocks, which may be made of any convenient size; and while it is down the weight is on the centre pin C, when carriages may be turned with ease and rapidity. By means of the stud I traversing the slot in the rod K during the first part of the motion, the table top is eased off the bearing on the blocks H H, before the rod K is set in motion to withdraw the blocks; and by the same means, in lowering the table, time is allowed for the blocks

to be pushed home before the table top is lowered upon them, so that the blocks are relieved from the weight whilst they are being moved. Fig. 11 is a plan of this turn table, showing the position of the long lever BB, and the horizontal rollers GG, that work round the centre pillar A. At the end of the lever L a weight is fixed to balance the weight of the table top to within a few cwts.; the balance weight not being made heavy enough to raise the table top without the exertion of a slight pressure on the handle M. Other modifications of this improved table might be described, but as the principle in them all is the same, viz., to carry the weight upon the centre pin when the table is being used, and upon the circumference when not in use, it is not necessary in the present paper to do so.

This mode of construction insures a *solid turn table*, one very *easy to turn*, and a very *durable* one; the working parts do not get deteriorated by the passing of trains, and are so placed that dirt cannot collect upon them; the extent of bearing surface at the circumference is greatly increased and prevented from becoming indented as in roller tables; a smooth and easy motion is obtained by turning entirely upon the centre, as no inequality of bearing surface has to be overcome; also less oil is consumed for the centre bearing than for rollers, and the working parts are more easily oiled. In roller tables an increased load increases greatly the resistance to turning, and after some years' wear they work more heavily; but in centre bearing tables much less difference is experienced. Also, the cost of foundation, instead of being more, is rather less than that required for roller turn tables with a live ring and rollers, as a continuous ring of masonry is not required round the circumference, but only six or eight blocks of stone, one under each arm of the centre pillar, in addition to the centre stone, which is required in both descriptions of turn tables.

Mr. Woodhouse inquired whether any of the tables had been put down, and where they were at work?

Mr. Lloyd replied that none of the plan with the lever had been put to work yet, the first one was not yet ready for trial; but a considerable number (about 60) of the first plan, without the lever, were at work very satisfactorily, many of them on the Syston and Peterborough line. They answered very well for goods stations, but not for

the main line, because they deflected too much at the outer edge for trains to run over them; they were found to keep in order very well, and some of them had been 10 years at work.

Mr. Gibbons thought there might be found a difficulty in getting the blocks to slide in always to their places under the table top, in the proposed lifting table.

Mr. Lloyd observed that there was only about 1 cwt. left unbalanced of the weight of the table top, so that there was very little work for the lever to do in lifting the top to the extent that was required for liberating the blocks, and pushing them into their places again. The whole weight of the top might be 3 tons for a 12 feet table, but it was nearly all balanced by the weighted lever, so that little more than the friction had to be overcome in lifting the top; the table was not lifted with a carriage on, as in previous plans of lifting tables, and was only to be lifted in the act of making it solid for the main line to let trains run over it, and in setting it free again, but was not lifted in the process of turning. The table top was only to be blocked for main line trains to run over, and was to be left free without supports at the circumference when turning and whilst carriages were pushed on and off the table for turning.

Mr. Cowper thought the height between the upper and lower rollers where they bore against the centre post was so small (making a great leverage at the circumference of the table), that a small play in the rollers would cause a considerable deflection at the edge of the table; so that it appeared liable soon to get out of level with carriages running on and off, if the top were not always blocked solid.

Mr. Lloyd replied that the rollers at top and bottom had the means of ready adjustment by screws, and no difficulty had been found in the tables at work, though they had no bearing at the circumference, while carriages and waggons were constantly being run on and off for turning. The only injurious deflection arose when trains of carriages passed over them; all those laid down were 12 feet diameter.

Mr. Sampson Lloyd observed that the centre post tables were found to have very little wear, and worked quite successfully; some of them had been in work 10 years without any bearing at the circumference; the

* An error in the position of the balance-weight in the drawing of Fig. 9, pointed out by some of the members, has been corrected in the engraving.

deep pillar engine tables had lasted very well for many years. The sliding blocks and lifting motion was a recent invention, for the object of making the table solid in the main line, when trains had to run over.

The CHAIRMAN remarked that in another plan of turn table, wedges were employed to make the top solid for the main line.

Mr. WOODHOUSE said that four wedges were pushed in by a lever, one under each line of rails, to give an additional bearing when the train passed over. He found the tables with live rollers answered much better than fixed rollers in goods warehouses and stations; the fixed roller tables worked very stiff.

Mr. LLOYD observed that the tables with a centre bearing only had an advantage in keeping all the working surfaces clean; the roller-path in ordinary tables was exposed to get dirty, increasing the resistance to turning.

The CHAIRMAN proposed a vote of thanks to Mr. Lloyd for his paper, which was passed; and expressed a wish for the results to be communicated of the practical working of the new turn table.

The following paper, by Mr. John Rolinson, of Brierley Hill, was then read :—

ON AN IMPROVED APPARATUS FOR PREVENTING EXPLOSIONS OF STEAM-BOILERS.

The object of this apparatus is to provide a self-acting means of closing the stop-valve, and opening the safety-valve, when a boiler is getting short of water, thereby cutting off all communication with the other boilers until the boiler is again properly supplied with water, and causing an alarm to call the attention of the engineman, before the water has got so low as to risk any injury of the boiler, preventing at the same time any increase of the pressure in the boiler from taking place.

Fig. 1, Plate 31, is a longitudinal section, and Fig. 2 a transverse section of the apparatus.

The float A falls when the water gets low in the boiler, and closes the stop-valve B, by the tappet C, and opens the safety-valve D, by the tappet E, causing an alarm by the rush of steam through the escape-pipe F, as soon as the water gets down to the level to which the apparatus is adjusted.

In a range of boilers working in connection, it sometimes occurs, from various accidental causes, that one of them becomes low in the water, causing danger of explosion, but with this apparatus such an accident is prevented ; and by closing the stop-valve and opening the escape-valve the boiler is cut off, and prevented from causing accident until properly filled with water again, when it resumes its former position, as the stop-valve then opens again and the escape-valve closes.

The pressure of steam is prevented from ever getting too high in the boiler, by the small cylinder G, with a piston one square inch area, which is open to the boiler on the underside, and is loaded on the top of the piston rod at H with as many pounds weight as the number of pounds pressure per square inch intended for the limit of the steam pressure. The piston lifts these weights in succession as the pressure rises, and at last lifts the lever of the escape-valve D ; a space is left between the different weights, so that the piston

has to move nearly to the top of the cylinder before it comes to the full pressure, and by the continual movement of the piston in the cylinder from the variations of pressure in the boiler, the piston is prevented from sticking fast, and is kept always ready for action.

The escape-valve lever is held up by the spring catch I if it continues to be lifted beyond a certain point, and then the escape of steam cannot be stopped, and the alarm will continue sounding until the engineman, returning to his duty, releases the valve lever from the catch, by pulling the handle K.

The whole apparatus is locked up in one cast-iron box, so that the engineman is unable to increase the steam pressure, or to prevent the sounding of the alarm and the escape of the steam whenever the water level is suffered to get too low from any cause, or the steam pressure gets too high. The apparatus is connected to the ordinary stop-valve fixed usually on boilers, and requiring only an alteration of the lever.

This apparatus has been at work for about two months, at Mr. Benjamin Gibbons', Corbyn's Hall, New Furnaces, near Dudley, and has proved quite satisfactory. It has been tried fully by blowing off the water from the boiler down to the level to which the apparatus was adjusted, when it was always found to act completely, and also when the pressure of the steam was raised too high.

Mr. Benjamin Gibbons said that the apparatus described in the paper was applied to one of a set of three boilers at his works, and proved quite satisfactory; it was found to act completely, either whenever the water was too low in the boiler, or the pressure of steam too high, and effectually prevented accident, and it appeared not liable to derangement.

Mr. Downing inquired whether there was the common safety-valve in addition, and what was the size of the escape-valve?

Mr. Rolinson replied, that an extra 5-inch valve was used, besides the ordinary safety-valve; the boiler that the apparatus had been applied to, was 6 feet diameter, and 30 feet long.

Mr. Downing thought the safety-valves were generally too small, and they would be better larger than 4 inches, by giving speedier relief to the boiler.

Mr. GIBBONS observed, that the size of safety-valves might be too much increased, as large valves would be more liable to stick fast; and he had never found the usual 4-inch valves not large enough.

Mr. RAMSBOTTOM remarked that a heavy float would be required to insure the action of the apparatus, and it would have to close the stop-valve against the pressure of steam in the boiler.

Mr. ROLINSON said the float was made large and heavy to insure certainty of action; but the steam from the other boilers would be always pressing on the top side of the stop-valve, and the pressure in the boiler on the under side of the valve was lowered by the steam being let off directly the apparatus acted.

The CHAIRMAN asked whether it was intended to apply a whistle to the escape steam-pipe, to make a more distinct signal?

Mr. ROLINSON replied that the steam was found to make sufficient noise in escaping without the use of a whistle, and there was the advantage of having no obstruction to its discharge.

Mr. GIBBONS remarked, that the whole apparatus might be locked up in a case of moderate size, about 3 feet high, including the float-chain and wheel, which would put it entirely out of the control of the men. He added that the whole cost of the apparatus was about £15 or £20.

The CHAIRMAN proposed a vote of thanks to Mr. Rolinson for his paper, which was passed.

The Meeting then terminated.

PROCEEDINGS.

December 7, 1853.

The Special General Meeting of the Members was held in the Lecture Theatre of the Royal Institution, Mosley Street, Manchester, on Wednesday, December 7, 1853; William Fairbairn, Esq., Vice-President, in the Chair.

The Secretary read the Minutes of the last General Meeting, which were confirmed.

The Chairman congratulated the Members on the occasion of holding the first meeting of the Institution in Manchester, and expressed his confident expectation that a meeting in a district which had taken so prominent a part in mechanical discovery and improvement would prove advantageous to the Institution, and promote its objects by bringing forward many papers on mechanical subjects, and accessions of valuable members.

He invited the visitors who were present to join in the discussion, and remarked that the object was to have a full discussion of the mechanical merits of the several subjects presented to the meeting, without taking up any questions of priority or property of patent right.

The following Paper, by Mr. William Fairbairn, of Manchester, was then read:—

ON A NEW DESCRIPTION OF WINDING ENGINE.

The invention of the Steam Engine, and the rapidly-increasing demand for its assistance in almost every condition of civilized life, has produced, and is still producing, changes to which it would be difficult to prescribe a limit. It has a creative power in itself, and no sooner do we effect—through its aid—the most marvellous enterprises, than its powers and capabilities increase, and it becomes,

not the limit, but the harbinger of future and still greater events. Sixty years have scarcely rolled over our heads since its first introduction. Twenty years from that date witnessed the development of its powers in the draining of mines, the crushing of ores, and the spinning of the finest wool. Twenty years more, and we find it battling with the storm, and waging war with the elements against wind and tide. And, carrying forward the metaphor, for the next and last twenty years we again find it spreading its arms over the surface of many lands, and hurrying onwards the ponderous train with a celerity which not many years ago would have been, by the most sanguine, considered incomprehensible. Such is the short history of the progress of the Steam Engine; the whole of these wonderful changes having taken place within the limits of the writer's own recollection.

The subject of the following communication is a Steam Engine recently erected by W. Fairbairn and Sons, for F. D. P. Astley, Esq., of Dukinfield, for the purpose of winding coal from probably one of the deepest pits on record. It may be mentioned that this pit is, or will be in a few months—when the lower seam of coal is reached—upwards of 650 or nearly 700 yards in depth. It is sunk upon the dip of the strata, which descend at an angle of about 23° in the direction of north-east to south-west. The seam is what is called the Black Mine, and is justly considered the finest quality of coal in this country; and is believed equal to the best Wall's-end.

This pit from its great depth presents several peculiar features as respects its locality, with respect to surrounding mines. Being at the lowest level, it drains several of the adjacent pits, and thus has the onerous duty thrown upon it of draining the whole of the superincumbent works, or those at a higher level. On account of this circumstance, a large pumping engine, constructed by the above firm, has been erected for clearing those mines of water; this engine, from its efficiency and peculiar construction, may perhaps come under the notice of a future meeting.

The Winding Engine, which is shown in Plates 32 and 33, is constructed on the "direct-action" principle—the same in fact as those which some years since were constructed for Her Majesty's frigates, Vulture, Odin, and Dragon, by William Fairbairn and Co., at Mill-

wall, and in which the writer was ably assisted by his then partners, Mr. A. Murray, now the Government Engineer at Portsmouth, and Mr. Hetherington, of Manchester.

The pit from which the coal has to be extracted is 12 feet in diameter, and is walled with Ashlar stone to a depth of about 40 yards from the top, and from thence to a depth of 201 yards is a wedging curb of oak. From this point it is made water-tight through layers of sand and porous rock, by metal tubing, to a depth of 248 yards from the surface, and the remainder is walled with either stone or brick, excepting only in those parts where the sides are of solid rock, capable of standing without interior support.

The shaft is divided into three compartments, one being used for the pumps, and occupying about one fifth of the area of the shaft. Of these pumps there are five sets—four of them plunger pumps of 15 inches diameter, and varying in length from 400 to 420 feet each, and the fifth and lower set a 12-inch lifting pump; the engine working them is upon the marine principle, and worked expansively by high-pressure steam.

The other compartments or divisions form a large space for the slide bars and cradles, each of which admit of four coal boxes, one above another, and in this position they are raised at once from the bottom of the shaft to the surface. Each box has four wheels adapted to the tram-ways below and above, and as soon as they arrive at the top, or descend to the bottom, the loaded boxes are exchanged for empty ones above, and the process is reversed at the same instant below.

The engine is, to the best of the writer's knowledge, one of the largest and most powerful of the kind ever constructed for such a purpose. The cylinder, which is 60 inches diameter, and 8 feet stroke, stands upon a cast-iron pedestal, firmly bolted to a platform of masonry resting upon four cast-iron beams stretching across the house, with their ends inserted under the walls on both sides.

These walls vary from 4 to 3 feet in thickness as they ascend, and rise to a height of 50 feet above the foundations; and thus, it will be observed, from the weight resting upon the iron beams, a degree of solidity is given to the foundations which could not otherwise be obtained, unless at greatly-increased expense in the erection of an Ashlar platform.

From the foundations to the entablature which supports the crank shaft and two fly-wheels, and on the periphery of which the wire ropes wind, rise four massive cast-iron columns, equidistant on each side of the cylinder, and these being secured by bolts to the foundations below, and the entablature above, a complete connection is thus effected, which acting in combination with the weight of the engine-house walls, gives a degree of solidity more than sufficient to resist the reciprocating action of the engine at a pressure much greater than 30 lbs. on the square inch.

In this description of engine, where the action is direct from the piston rod to the crank, it usually occurs that the preponderating weight of the connecting rod, crank, and piston causes great irregularity of motion, and to remedy this defect, balance weights have frequently to be attached to the fly-wheel or some other part of the engine, to cause uniformity of motion. In the present engine these adjuncts are not required, as it has been contrived to balance the difference of weight in the up and down strokes by the lift of the air-pump, as may be seen by the drawings at A, B, and C, which show the fixed and oscillating levers. This answers the double purpose of exhausting the condenser and of forming radius bars for the direct vertical motion of the piston. In this operation a perfectly direct motion is not only effected, but the parts are so nearly balanced as to enable the engine-man to raise and lower any weight, however heavy or light, with an extraordinary exactitude; and in fact such was the accuracy of the motion, that the "sinkers" availed themselves of the engine for the purpose of lowering, raising, and setting the stones used in walling the sides of the pit.

The working of the engine is accomplished by eccentrics, from a shaft D, which extends from the crank to the opposite wall. These eccentrics give motion to the plug rod, which works the valves, and acting upon the lever or handle E, enables the engineer to regulate the speed and reverse the motion at pleasure. All these valves are double-beat, upon the equilibrium principle, as shown on a larger scale in Fig. 3, and the result is, that they are worked at any amount of pressure, without any increase of balance in the handling or the working of the engine.

For the purpose of winding or raising coal, flat wire ropes are now in general use, and those employed at this pit are of that

description. They each weigh about 2 tons, or 8 tons with the addition of the cradle and boxes. These boxes each contain 8 cwt. of coal, collectively 32 cwt., which is the load to be raised from the bottom of the pit to the surface in one minute. This gives a velocity of nearly 2000 feet per minute, or about 23 miles an hour, and taking the speed at and the height to which the load is raised, we have a power of nearly 220 horse, independent of friction, and the immense preponderance of rope which has to be overcome at starting from the bottom of the pit. This is to some extent equalized by the balance chain, which unrolls itself from the drum F in its ascent within the well behind, till the cradles meet, when the motion of the balance chain is reversed, and the chain begins to rewind upon the barrel as the descending rope begins to preponderate over the ascending rope.

Taking all these conditions into account, the engine will be found in regular working duty to be giving out a power varying from 400 to 450 horse-power.

The Chairman remarked that he had brought the paper before the meeting, simply as an account of an unusually large size of winding engine, the largest he believed that had ever been erected. The depth of the pit at present was very great, 500 yards, and when completed to the full depth would be 700 yards; a depth he believed considerably greater than any other pit he was acquainted with; the deepest was probably that at Bishop Wearmouth, which varied from 400 to 500 yards. This great depth, and the large quantity of coal to be raised, required the speed to be much greater than usual, and they had succeeded in safely working at a velocity equal to 23 miles an hour, in drawing up four boxes loaded with 1½ tons. This was a point of great importance in the erection of the engine, as the supply of coal could not otherwise have been all raised by one shaft. The engine, which was direct-acting, occupied very small space in proportion to its power, and the large unbalanced weight on the down stroke of the steam cylinder was so effectually neutralised by the resistance of the up stroke of the air pump, that the engine could be managed with the greatest uniformity of motion required.

Mr. DYER inquired whether the same seam of coal was worked at a higher level at any other place?

Mr. FAIRBAIRN said the pit had been sunk at the lowest point of the portion to be worked for the sake of drainage, and the workings would be extended upwards from the pit; he was not aware how much higher the seam was elsewhere.

Mr. DYER observed that the rapid progress in the invention and application of the steam engine was very remarkable during the half century since its commencement by Watt, and was a great encouragement to further progress. The power of mind over matter seemed destined to proceed with an accelerating force; the last 25 years had done much more than the previous 25 years of the century.

He proposed a vote of thanks to the Chairman for the interesting and valuable communication he had brought before the meeting; and the vote was seconded and passed.

The following Paper, by Mr. Benjamin Fothergill, of Manchester, was then read:—

ON AN IMPROVED WATER METER.

Amongst the various objects to which men of mechanical genius have directed their attention for many years, that of producing a machine for accurately measuring the flow of water has been considered a great desideratum; and amongst the number which have been submitted to the public, that of Mr. Thomas Taylor, of Manchester, which forms the subject of the present paper, appears to contain all the essentials of a complete and correct meter.

A meter is required to sustain the greatest pressure,—the flow must not be interfered with by obstruction or friction, so as to hinder its ascent to the highest point of its source,—it must measure correctly under every variety of pressure, and when subdued to the smallest amount of inlet must indicate the quantity passing through the meter,—and durability or non-liability to wear and tear must be an important feature, without which the machine would be of little value.

It will be seen that these properties are all embraced in the meter of Mr. Taylor, and that it is admirably adapted to answer all the purposes for which water meters have been designed. In consequence of water being almost incompressible, the amount of water contained in a pipe or vessel of a given dimension must be the same under all pressures, and therefore if a machine could be constructed that would indicate correctly the speed at which the water flows through a pipe of a given area, the quantity might be ascertained to the greatest nicety. In Mr. Taylor's meter, now to be described, this object has been achieved.

The idea that struck him for ascertaining the quantity of water passing through the machine was as follows:—He first determined the area of the pipe through which the water was to flow (say equal to two inches diameter), and in the next place the circumference of the wheel or drum that was designed to move simultaneously with the flow of water (say 24 inches circumference). The next question would be, how much water will a 2-inch pipe contain in 24 inches length; and supposing this to be one gallon, then in that case every revolution of the wheel or drum would indicate one gallon as having passed through,—ten revolutions would be ten gallons, and so on, the index being set so as to register the exact quantity passing through the meter at each revolution.

The Meter, which is shown in Plate 38, consists of a cylindrical vessel or cistern AA, of a size proportionate to the bore of the pipe that is to receive and discharge the water; inside this vessel is a drum B revolving on its axis in a vertical position, and the stream of water passing through the meter is distributed upon the drum at each side of the meter, the water entering at the two inlet openings CC, and being discharged at the two outlets DD. The registration is given by a train of wheels at E, connected with the drum, and carried to the indicator K.

The drum is constructed of gutta-percha, thereby preventing liability to collapse or corrosion, and making it of the same specific gravity as water. The water contained in the meter causes the drum to be buoyant, by which arrangement the drum is made to revolve by the slightest action of the water against the blades or buckets.

The arrangement of the thoroughfares or pipes FF outside the

meter, communicating with the inside and round the drum, for the delivery and exit of the water, produces a rotary motion in the water, thereby causing the drum, in addition to its buoyancy and vertical position, to be more certain in its liability to revolve under the slightest pressure of water.

The branch pipes and valves GG from the thoroughfares for the ingress of the water, are so shaped that they bring the immediate action of the stream passing through the meter on the drum. The equal distribution and division of the stream (however small it may be) at each side of the drum, render its liability to wear and tear very slight; and whatever the pressure or power of the stream may be, by the above arrangement it is rendered neutral in causing more or less friction upon the axles or pivots of the drum, that friction being the same under any pressure, and only sufficient to keep the drum in its position.

The valves GG (shown enlarged in Fig. 3), are constructed after the plan of a common clack valve, and close the apertures of the inlets, excepting a small tube H fixed in the centre of the clack, and projecting so as to cause the stream of water to come into immediate contact with the buckets of the drum. Each valve is closed by a simple arrangement of a small india-rubber spring I, attached to an eccentric above the valve, the spring being regulated by winding it backward or forward on the pin L (which being once regulated becomes a fixture, and needs never to be altered), so as to give more or less pressure to close the valve. The use of these valves is occasioned by the fact that although the pressure on the drum may be neutralised, yet there is necessarily a slight amount of friction to overcome in working the train of wheels to the indicator, which is done by the spring closing the valve, and causing a compression of the stream, so that no water is allowed to pass but what forces through the valve-tube H. The valve is only brought in requisition when a very small quantity of water is passing through the meter, and as the stream increases the valve is not required to insure correct measurement; it is then thrown open by the vanes MM, which are fixed on the valve spindles, and are carried outwards by the circulation of the water in the meter, when there is a considerable stream passing through·

The certainty of registration of this meter, its non-liability to wear and tear, and its certainty of working under the highest or lowest pressures, are caused by the buoyancy of the drum, its vertical position, and the adaptation of the inlet-pipes and compression-valves to bring the stream, however small, into immediate contact with the drum, and cause it to revolve.

Meters on this construction, of various sizes, and placed in different situations, have been in operation for several months; and the inventor has been furnished with several testimonials of their efficiency.

Mr. Fothergill showed one of the meters in operation before the meeting, which had been brought by Mr. Taylor for the purpose, and exhibited separate specimens of the gutta-percha drum and regulating valve. He observed that the friction of the drum was very small, as its weight was all supported by the water, being adjusted to the same specific gravity as the water, and the resistance from friction of the wheelwork, and the stuffing box for the spindle at the side of the meter, would be very slight, on account of the great leverage over it at which the water acted on the circumference of the drum; there was consequently so exceedingly small a resistance to be overcome in making the drum revolve, that the smallest stream of water impinging on the drum and flowing round its circumference was sufficient to overcome its inertia, and cause it to rotate with a velocity proportionate to the quantity of water discharged, being the amount of moving force. The velocity with which the circumference of the drum revolved, was consequently a correct measure of the quantity of water discharged upon it; and this had been found to be the case in practice, for all the meters had been worked under very extreme differences both in pressure and in velocity of discharge, and those he had examined or was acquainted with had proved correct in measurement throughout. The meters had been used with great advantage to measure the quantity of water supplied to boilers, so as to ascertain correctly the water evaporated by the coals consumed, which was important information in reference to economy of working, and could only be satisfactorily ascertained by means of such a meter.

Mr. THOMPSON said he had had three of the meters at work for several months in Manchester; one a large meter to measure the water raised into a 3000 gallon cistern, and two others employed to measure the water supplied to boilers. He had tested the meters regularly once a week for some time, and found that they uniformly registered correctly within one half per cent.; they had kept in good order, and gave entire satisfaction.

The CHAIRMAN remarked that he had recently witnessed a trial of the meter with several members of the Institution, in which the meter was connected to a cistern containing 100 gallons of water to about $\frac{3}{4}$ inch depth; the register of the meter was found to be correct for each 100 gallons drawn from the cistern, both when running full bore and when discharging only by a very small stream. The meter appeared therefore to be accurate under both extremes, and he thought it was a very ingenious invention, and had an important advantage in the simplicity of construction.

Mr. PERRING said he had tried a series of experiments on four different meters, and this was the only one that he found not to fail in registering the quantity of water when discharged in a very small stream.

Mr. ROFE inquired what was the highest pressure under which the meter had been tried?

Mr. FOTHERGILL replied that one of the meters was working under 220 feet head of water at Bolton, and was found to work quite satisfactorily. The largest of the meters that had been made, was at Dukinfield, where it was supplying 72,000 gallons per hour.

Mr. ROFE inquired what examination was found to be required after the meters had been in regular work for a considerable time? and whether there was any effect upon the gutta-percha drum and the india-rubber spring from the action of the water? He should fear the india-rubber spring was too delicate for such a purpose.

Mr. FOTHERGILL said that after one year's constant work both the gutta-percha and india-rubber were found to remain perfect and unaltered, and he saw no reason to doubt that the experience of further years would give the same result; the water did not have any action upon them; it would not however do to have a gutta-percha drum with hot water, and in applying the meter to measure the supply of water to boilers, care must be taken that it was not exposed to water warm

enough to soften the gutta-percha. If the meter were required to measure hot water, a hollow copper drum should be used.

Mr. Thompson observed that he had a meter with a copper drum in constant use for some time measuring hot water, and it had proved quite successful.

Mr. Rofe asked whether there was any reason besides its lower cost for using gutta-percha rather than copper in making the drum?

Mr. Fothergill replied that independent of the cost being less, the gutta-percha had an advantage in the convenience and accuracy with which it could be manufactured; it was pressed into an iron mould, accurately made to the form of the drum with all the teeth, and the sides being then stuck on completed the drum.

Mr. Shipton remarked that a copper drum might also be objectionable, from being made accidentally out of balance, by a lump of solder left in one part.

Mr. Cowper said he did not see how the measuring of the water could be effected by the meter with sufficient certainty, as the measurement was not made by filling the buckets successively in the circumference of the drum, they being already full of water, but only by the velocity communicated to the wheel by the stream of water flowing past it; and he did not think the measuring could be accurate at different velocities, as the friction would not be constant, and therefore the difference between the velocity of the wheel and that of the water would not be constant.

The Chairman observed that it appeared to be considered that the buckets or teeth on the drum were carried forward and floated with the stream at the same velocity as the stream, in consequence of the very little resistance to retard the drum. He was certainly surprised at the accuracy of the results obtained in the experiments with the meter, and thought it well worth a complete trial, as a simple and ingenious machine; and he proposed a vote of thanks to Mr. Fothergill and to Mr. Taylor, which was passed.

The following Paper, by Mr. Edward Jones, of Liverpool, was then read:—

ON THE AMERICAN DRY CLAY BRICK-MAKING MACHINE.

This Machine, the invention of Mr. Culbertson, of Philadelphia, is one of the numerous American inventions imported into this country, and has been worked in a most satisfactory manner for a considerable period, in several parts of the United States. The simplicity of construction of this machine, and its complete adaptation to the intended purpose, are the writer's reasons for bringing it before the meeting. It will be seen from the drawings and model that there are few wearing surfaces in the machine, and they are not likely to get out of order.

A longitudinal section is shown in Fig. 1, Plate 36, and transverse sections in Figs. 2 and 3, Plate 37.

A is a strong cast-iron frame, fixed to a brick or stone foundation.

B, a portion of the frame for receiving the journals of the press-wheel and roller shaft.

C is the mould carriage, containing 14 moulds, each provided with a moveable bottom, with stems projecting through the carriage, by means of which, and the lifting bars D, the bricks are raised from the moulds, as the lifting bars D are carried up the inclines E E on friction rollers by the forward motion of the carriage C.

F, slides for bearing off, which in the working machine are made self-acting.

G is the rack, bolted to the bottom of the carriage, worked by the spur-wheel H.

I I is the clay box, fitting close on to the face of the mould carriage, and secured to the frame.

K K, the hopper.

L, the press-wheel.

M, bearing wheels, to sustain thepressure on the mould carriage.

N N are two spur-wheels to cause the press-wheel and mould carriage to travel at uniform rates.

O is an internal and external spur-wheel.

P is the pinion on the vibrating shaft, producing a reciprocating motion of the mould carriage, by what is generally known as the mangle motion.

A steam pipe is provided, marked Q, which can be used if it is found necessary, to warm the press-wheel, which is cast hollow, to prevent the clay adhering to the surface.

This machine enables the manufacturer to continue his operations during the whole of the year, as the clay used is in a semi-dry state, or just as it is dug from the ground, and the bricks when made are taken direct from the mill to the kiln.

The machine is self-feeding and self-delivering, and will, with ease, turn out 25,000 bricks per day, harder, smoother, and containing less water, than when made by hand, and at a much less cost. Instead of the present mode of casting, tempering, weathering, &c., the clay is taken direct from the bank to a pair of rolls running at different velocities, so as to break it up thoroughly, and from thence to the mill by means of elevators or other mechanical appliances.

The pressure upon the clay in the machine is gradual and continuous, allowing the air to escape freely as the clay is forced into the mould; and as each mould passes twice under the cylinder, receiving clay from the hopper each way, the brick is made full and perfect in all its edges.

Bricks of any shape can be made with this machine by using suitable moulds.

In a commercial point of view, the following statement will show the value of the invention.

The present prices of brick-making in Lancashire are:—Casting 10d., faying 2d., moulding 1s. 8d., tempering 1s. 8d., wheeling off and walling 1s. 8d., carrying off 9d.; making a total of 6s. 9d. per thousand.

Taking the working days at 250 in the year, an average of 25,000 per day is equal to 6,250,000 per year, costing at 6s. 9d. per thousand, £2104 7s. 6d.

By means of the machine we have:—First cost, including steam engine, foundation, crushing rolls, and all other machinery required, £1400.

	£	s.	d.
This at 15 per cent. for interest and depreciation is	210	0	0
Coal, oil, and engine driver, for 250 days .	190	0	0
Getting clay and wheeling to rolls . .	190	0	0
Wheeling off, and attending to machine .	200	0	0
Incidentals	50	0	0
	£840	0	0

or 2s. 8½d. per thousand, or a gross amount of saving of £1264 7s. 6d. on the year's work; being nearly the entire cost of the whole of the machinery and buildings.

Mr. Jones exhibited a working model of the machine, with full-size specimens of the bricks, baked and unbaked.

The Chairman inquired whether the pressure upon the bricks in the machine could be varied, if required?

Mr. Jones replied that it could only be done by adjustment of the wheel; the form and size of the press-wheel regulated the drawing in of the clay under the wheel and the degree of pressure into the moulds.

Mr. H. Smith asked how long the machine had been at work?

Mr. Jones said it had been working for nine years in the United States, where machine-made bricks were used to a large extent on account of the greater cost of labour; the machine had only been a short time at work in this country. The comparative calculation of cost given in the paper was founded on the rates of brickmaking in the last season at Wigan.

Mr. Dyer thought there would be great objections raised in that neighbourhood to making bricks otherwise than by hand labour; the prejudice was so great amongst the labourers against the introduction of any new machinery, lest it should supersede their employment.

Mr. Jones remarked that this machine would be a great advantage to the brickmakers, because they could be employed for the whole year continuously, as the bricks did not require drying; but it was now a very precarious employment, being dependent on the season and weather. There was now one of the machines at work at Kirkdale, near Liverpool, making excellent bricks in all weathers, specimens of which were before the meeting.

The Chairman said he trusted that the opposition to the introduction of machinery was now rapidly disappearing, being only the effect of ignorance; and it was becoming more generally understood that the farther the introduction of machinery into a manufacture was carried, the more manufacture would thrive and increase. He inquired what was the comparison of the number of bricks per day that could be made by hand-labour and by the machine?

Mr. Jones replied that the machine turned out 25,000 bricks per day, and a good brickmaker made 6,000 or 7,000 per day; but these had all to be dried before they could be burnt, and it was a great advantage in the machine-made bricks that they did not require drying, but were taken direct from the machine to the kiln, making an important economy of time, as well as preventing the great waste that occurs from injury of the bricks when exposed to the weather.

The Chairman proposed a vote of thanks to Mr. Jones for his communication, which was passed.

The following paper, by Mr. Benjamin Fothergill, of Manchester, was then read:—

ON THE COMBING OF FIBROUS MATERIALS.

In investigating the various mechanical contrivances for combing fibrous materials, a reference has necessarily to be made to those instruments which the ingenuity of man originally contrived for the accomplishment of this object, and there appears no doubt that the common or ordinary comb, made sufficiently long and strong in the teeth, was first used for this purpose; the defects of that instrument, however, would soon become apparent, and the necessity for additional numbers of rows of pins or teeth would naturally present itself, so that the operator might be able to collect and hold the various lengths of the fibres of the wool as he lashed or looped them on to the teeth of the comb.

Such was the state of things when the Rev. Edmund Cartwright, of Doncaster, in Yorkshire, (a name ever to be revered and respected) turned his attention to the subject, and contrived a machine for combing wool, for which he took out his first patent in 1790, and a second in the same year; but it was not till nearly two years afterwards that his machine was brought to what he called "its state of simplicity and perfection," for which he took out a third patent in May, 1792. Concerning the latter he says:—"This machine is I believe the first of the kind; at least, all former attempts (if there have been any) must have proved abortive, as previous to my invention, no wool was ever known to have been combed any other way than by the slow and expensive process of hand labour."

The magnitude of this invention in respect of its object and its importance to the Woollen Manufacturers, may in some degree be estimated

by the quantity of combing wool annually grown in this island, which according to the most approved calculations cannot be less than 300,000 or 400,000 packs; the average expense of combing which by hand may reasonably be laid at £800,000 or £1,000,000. To show that this calculation is not far from the truth, it need only be recollected that the body of wool-combers is supposed to be nearly 50,000, among whom the alarm which the introduction of this machine has occasioned is well known; upwards of 40 petitions, from various parts of the kingdom, were presented to parliament during the course of the present session, for its suppression; and for this purpose a bill was brought into the House of Commons by the friends of the petitioners; it was however thrown out by a great majority; indeed, had the principle of the bill been admitted, there would have been an end to all manufacturing improvements; but setting even this consideration aside, on other principles of policy, it would have been inadmissible; and even on the principle of humanity to the petitioners, the only ground on which it could be defended, there is reason to believe it would not have been necessary, the introduction of new inventions or improvements, whatever may be their value, being in general so gradual as to affect those whose occupations they interfere with almost imperceptibly.

The drawing of this interesting machine, shown in Plate 34, is copied from the original one in the Patent Office. Fig. 1 is the crank lasher (a contrivance intended to supersede the man's arm and hand in lashing the wool into circular comb). A a tube through which the material, being formed into a sliver, and slightly twisted, is drawn forward by the delivering rollers E. B a wheel fast upon the cross-bar of the crank. C a wheel on the opposite end of whose axis is a pinion working in a wheel upon the axis of one of the delivering rollers.

When two or more slivers are required, the cans or baskets in which they are contained are placed upon a table under the lasher (as represented at D), which, by having a slow motion, twists them together as they go up.

In Fig. 2, F is the Circular Clearing Comb, for giving work in the head, carried in a frame by two cranks W W.

G G, the Comb Table, having the teeth pointing towards the centre, moved by cogs upon the rim, and carried round upon trucks like the head of a windmill.

H H, the drawing rollers. I I, callender or conducting rollers.

Under the table is another pair of rollers for drawing out the backings, but these are not shown.

Such is a description of Cartwright's machine, of 1792, and it is a singular fact that although he patented another machine in which considerable improvements were introduced, yet he did not perceive the great evil which existed not only in his own machines, but also in the mode of treating the wool by the *hand* comber; and although a great number of patents have been taken out for improvements in machinery for combing wool from the time of Cartwright to the present period, yet all of them up to the year 1846 continued to overlook the fact that in the process of combing the majority of the fibres were broken in two, producing not only more "noil" or waste, but considerably shortening the otherwise long fibre; and although they had the practice of the hand flax-dresser, as well as the improved machines for heckling or combing flax before their eyes, yet they did not discover or attempt any means to remedy this serious defect.

This was the state of things when, in 1846, Josué Heilmann, of Mulhausen, in France, introduced his improved machine "for the purpose of combing cotton as well as wool and other fibrous materials; into which machine the fibres as they come from the dressing machine are introduced in the form of a lap, sliver, or fleece, which is broken asunder, and the fibres are combed at each end, and the long and short fibres are separated, the long ones being united in one sliver, the short ones in another; and they are passed out of the machine thus separated ready for drawing, roving, and other subsequent operations."

A drawing of Heilmann's machine is shown in Plate 35, in which Figs. 1, 2, and 3 show three successive positions of the moving parts.

The object of the machine is to avoid the old and injurious process of "lashing" the fibres round the teeth or pins of the combs, and the contrivance to effect this object is as follows:—The end of a "sliver" of uncombed wool A is delivered into the machine, and the front end B of this sliver is combed by the pins C C fixed on one portion of the surface of the revolving cylinder D, whilst the entire mass of the sliver is held tight between the holding "nippers" E F, as shown in Fig. 1; which shows the position of the machine when the combing by the pins

C C is just commencing. After these pins have combed out the short fibres and other refuse from the sliver, the nippers E F open, as shown in Fig. 2, and at the same moment the moveable comb G is made to pierce through the sliver, by the pins H H lifting the lever attached to the arm of the comb; and the drawing roller I coming at the same time into contact with the fluted portion K K of the cylinder D, lays hold of the front portion B B of the fibres (which have been combed), and draws the uncombed portion through the fixed combs L L and the moveable comb G, thus effecting a combing of the tail end of the portion of the sliver which is thereby detached.

The machine is then made to pass another portion of the sliver forward from A, by the action of the cam M, which draws back the nippers towards the fixed comb L, as shown in Fig. 3, when the nippers are closed and pulled down by means of the lever N and rod O; and the cam M having passed into the position of Fig. 1, the lever P which vibrates from a fixed centre R and carries the nippers by the centre S, returns to its original position as in Fig. 1, causing the nippers to draw forward another length of the sliver from A. The entire process being repeated with the succeeding length of fibre, another portion is combed and detached, and is carried forward by the drawing roller I, and pieced on to the preceding portion; the combed wool leaves the machine in a continuous sliver, passing through the calender rollers T T, into a can U, from which it is taken to the after processes of drawing and spinning.

The pins C C on the cylinder D are cleaned by a revolving brush V; and the short fibres and refuse are delivered and struck into the card teeth on a revolving roller W, from whence they are "doffed" by the knife X.

Thus in this way the fibres are combed and laid parallel by the side of each other without being broken; and to such perfection has this machine been brought, that not only some kinds of wool which could not be combed by machinery prior to Heilmann's invention, but cotton, silk, and tow are now undergoing this new mode of treatment with decided advantage and complete success: and the accompanying specimens laid before the meeting will show the difference between the ordinary carded cotton and the combed cotton. Besides, this machine can be so constructed as to take out different lengths of fibre from one

sample of material, as shown in the accompanying samples of silk, and during the first operation it selects all the longest fibres, which are the most valuable; the remainder are then put through the next machine, which has the nippers and rollers placed closer together, and a second, though shorter class of fibres are combed and selected; it is again submitted to a third operation, and the shortest length is selected, and the remainder, it will be observed, is nothing but "noil" or waste. Such is the character of this beautiful invention, which is well deserving of consideration; and it may be observed that this machine is now being introduced into the Manchester cotton mills, where the higher classes of numbers are spun.

Mr. Fothergill exhibited a series of specimens, from France and Yorkshire, of cotton, flax, and silk, illustrating the process of combing, and the various degrees of fineness in quality that could be produced; and showed the effect of looping the material over the teeth of the comb and breaking the fibres as in the old process of combing, and the superior result of drawing out the long fibres unbroken by the improved process of Heilmann described in the paper. He stated that previously nothing farther could be done with the refuse tow left from combing flax, beyond carding and spinning it into a coarser class of yarn; but by the improved process as great a value could be obtained from that refuse by additional combing as was obtained from the first combing by the old process.

Mr. Dyer said he had witnessed the operation of the machine at Mr. Houldsworth's mill, and was very much struck with the perfection with which the machine selected the long from the short fibres; it was certainly a highly ingenious and important improvement in the process of combing, and appeared likely to make a great change in the treatment of fibrous materials.

Mr. Fothergill remarked that one great advantage in the improved process was that the fibres obtained were all of the same length, but there used to be a mixture of many different lengths, on account of the fibres being so much broken in the combing; also this machine could be so arranged as to select all varieties of length of fibre without

breaking them, and he had known as many as seventeen different lengths of cotton picked out from one sample. The uniformity obtained in the length of fibre was an important advantage in spinning, and it was attracting great attention in the spinning districts.

The CHAIRMAN observed that the new combing machine was a very beautiful mechanical invention, intended to perform a delicate and difficult process, and it appeared to be quite successful in accomplishing that object, by effecting a very important improvement over the former process. He proposed a vote of thanks to Mr. Fothergill, for his valuable and interesting paper, which was passed.

The following paper, by Mr. William Fairbairn, of Manchester, was then read:—

ON THE RETARDATION AND STOPPAGE OF RAILWAY TRAINS.

The general principle of railway-carriage breaks, namely, that of retarding or stopping the revolution of the wheels by the pressure of break-blocks against their peripheries, is limited in its application to the single carriage, in which the power is applied by the guard's hand; and looking at the present greatly-increased velocities of trains, and their probable acceleration, it becomes a very important question, whether some more powerful and speedy control is not required over the motion of the train than can be obtained by the ordinary plan of a break upon one or two guards' vans, and upon the tender.

Many plans have been proposed during the progress of the railway system for the accomplishment of this desirable object, and amongst them may be mentioned, as one of the most practical, a plan invented some years since by Mr. Robert Heath, of Moss Side, near Manchester, which consisted of break-blocks fixed in slide-bars in each carriage, and worked by a lever with a weight upon the end of it, adjusted to give the requisite pressure upon the wheels. When the pressure of the breaks was required to be taken off, the ends of the levers were lifted by means of a tension-bar and chains, which extended the whole length of the train, and were worked by a rack and pinion within reach of the guard. The peculiar feature in this break, distinguishing it from the ordinary hand breaks, was the employment of a weight to put on the pressure of

the breaks, independent of the power of the man's hand, and simultaneously in every carriage of the train, giving an important advantage in the great increase of power available for stopping the train, and the promptness of its action, the guard having only to release a catch in order to put on all the breaks at once, and employing his own power only in lifting off the breaks afterwards, by means of the rod and chain communicating with each carriage. In a practical trial of these breaks in 1848, with a train of five carriages and a van, all fitted with the breaks acting together, and the tender-break also used, the following results appear to have been obtained:—

Speed of Train when Breaks were applied.	Descending gradient.	Distance run after Breaks were applied.
40 miles per hour.	1 in 100	148 yards.
45 " "	1 in 100	163 "
50 " "	1 in 82	232 "
55 " "	1 in 200	264 "

Numerous other plans have been suggested, and tried at different times, for the purpose of arresting the motion of railway trains, within shorter distances than can be effected by the ordinary hand breaks; but none of them appear to have answered the purpose satisfactorily, or effected any material change in the breaks in general use.

The next improvement requiring particular notice, is the break recently invented by Mr. James Newall, of Bury, the more immediate subject of the present paper.

The immense extension of railway communication, and the number of persons conveyed, involve considerations of such vast importance, as to render any attempt to obtain increased security a subject of deep interest, in whatever form or direction that security can be effected. If the causes are considered of the railway accidents which from time to time take place, they may, in many instances, be traced to those arising from the inability to bring a train from a state of motion to a state of rest, or in other words, to absorb the momentum of the train within a given distance of space, and that without injury to the carriages, or endangering the safety of the passengers. This has always been a defect in railway travelling, and many of the serious accidents arising

from collisions of one train running into another, have occurred from the want of power to stop the train in motion before it arrived at the point of contact.

This to some extent has been accomplished by Mr. Newall's break, and from the results of the experiments made on the East Lancashire Railway, on the 7th November last, as described subsequently, this break appears to bid fair to accomplish that object, or at all events to become the precursor of further improvements, giving increased security to railway travelling.

The following is a description of Mr. Newall's break, which is shown in Plate 39 :—

The object of this invention is to work as many of any description of breaks as the weight of a train may require, either from the engine or guard's van, or from any of the carriages in the train. A lever, A, is fixed to the centre shaft of the break, under each carriage, to extend to the end of the carriage; the length of this long lever, as compared with the short arms which apply the break-blocks to the wheels, is about 11 to 1. A cylinder, B, is fixed to the end of each carriage, containing a spiral spring, which will shut up inside the cylinder to 14 inches length when compressed; under this spring is placed a cross-head, C, which projects out of the cylinder at each side, and is acted upon by the spiral spring; this cross-head is connected to the end of the lever A, and the spring gives a pressure of about 56lbs. at the end of the lever, which multiplied by the leverage, 11 to 1, gives a pressure on the four wheels of about 616 lbs ; this pressure is found sufficient for ordinary stoppages. Two upright racks, DD, are connected to the cross-head, C, and they are acted upon by a pinion, E, fixed on the main shaft at the top of the carriages; only one of these racks is in action at a time, but two racks are used, because when a carriage comes to be connected, and is the wrong end about, one rack can then be thrown out of gear, and the other into gear, so as to reverse the motion, which is done by sliding the frame carrying the pinion E, by means of a small lever at the top of the carriage. The connecting shaft F is carried on to each carriage, and on to the tender at G; and if the guard's catch is on, in his van at H, the engine-driver, by giving a lift at the handle G, as if taking the breaks off, liberates the guard's catch, and

so *(vice versa)* all these catches are made to fall back from the ratchets by balance weights (as shown enlarged in Fig 5), on the weight being taken off them; as soon as the catch is fallen back, the guard or driver lets go the handle, and the breaks apply themselves by the pressure of the springs, but the guard or driver can apply as much more pressure as he thinks fit by giving the handle a few extra turns The coupling of the shaft F between the carriages is effected by a spring catch T, similar to a brace and bit, as shown in Fig. 3. A man can couple and uncouple six carriages in as many minutes; each coupling is made to offer either end by means of a swivel joint, so as to couple with the next carriage, whichever end may be put to it Five or six turns of the handle on the tender or van are sufficient to apply the breaks, or take them off, and one guard can work six of them easier and quicker than one of the ordinary breaks. After the train is marshalled in the usual way, the porter drops all the breaks on, and then mounts the carriage and couples each; in addition to the spring stud on the opposite side of the coupling, a thumb-screw is used as an additional safety. When all are coupled together the apparatus can be worked from any portion of the train, or from the tender; the shaft T which passes along the top of the whole train is made of 2½in. iron tubing, about ¼in. thick, and revolves in light cast-iron pedestals, and on each carriage it is made with an expanding slide M of 1¼in. square iron, working in a steel square, welded in the end of the other tube; the steel square is about 2½in. long, and the square bar 6ft. long. If the shackle becomes broken this square bar is drawn out of the tube, and the breaks instantly are liberated and apply themselves. Double ball-and-socket joints NN are provided at each coupling, to allow for differences in the heights of the carriages, and curvature of the trains.

In addition to the advantage of being able to stop the trains in so much shorter a time, a saving of 70 per cent. is stated to be found in the wear of the tyres; this saving in wear is effected by not having to skid or stop the revolution of the wheels, so as to cause them to slide on the rails. Trains are being also fitted up with the connections running under the carriages, but the principle is the same; the connection underneath being sometimes preferred as more convenient for carrying it past carriage-trucks, horse-boxes, &c.; if the connection is to be carried over the tops, the carriage-trucks require a frame at each end to support the rod; the connection can easily be taken over the horse-

boxes. The breaks need not be applied to every vehicle in the train, if desired, the coupling-rod only being required to be continued throughout the train, which then acts as a perfect signal for communication between the guard and engine-driver when there is danger of a collision.

The following objects are proposed to be obtained in this break :—

1st.—A direct communication between the engine-driver and the guard; and it has to be observed that this communication is always available by either party, in the event of a sudden and unexpected discovery of danger or obstruction upon the line, and this accomplished, not by ringing a bell or blowing a whistle, where time is lost before the break can be applied, but by on instantaneous application of the break itself, or rather the whole of the breaks, which in every case is the first intimation of the presence of danger, and the remedy to avert its occurrence. This appears to be an important feature in the plan, it is easy of application, and probably the best signal that can be made between two officers of such responsibility as the driver and guard. In the experimental trial of this break, this was an important feature, and one that could not be mistaken at the moment the breaks were liberated; the check (it could not be called a shock), was so distinctly felt, as to arouse the attention of less vigilant persons than guards and drivers, who are, or should be, constantly on the look-out.

2nd.—The instantaneous and simultaneous application of the break to every carriage in the train; and the immediate application of a retarding power to a body of such magnitude as a train in motion, and that without endangering its security, is an advantage of great importance in this plan. The breaks are not screwed against the peripheries of the wheels, as is done in the usual way by the guard in the carriages, and the fireman on the tender; but the whole of the breaks (even if 30 in number), are dropped at once upon the wheels, and by the expanding force of the springs in the vertical tubes, the effect is such as to act as a signal from the driver to the guard, or *vice versa* from him to the driver; no time therefore is lost, and the retarding force is in operation upon every carriage at one and the same time, and by this operation a few

seconds only are required to reduce the velocity and absorb a considerable portion of the momentum of the train. This simultaneous action is therefore of the utmost importance, particularly in the event of a threatened collision, which by this means, if not totally averted will assuredly be greatly mitigated in its effects.

3rd.—The power which either the engine-driver or the guard have together or separately to sledge the train, or to increase or diminish the pressure on the breaks. In applying this plan of breaks to a railway train, particular care is required in the first instance when the train is marshalled, to regulate and adjust the breaks upon each carriage, so as to give neither more nor less than the required pressure. This it will be observed is a constant quantity, and the remaining pressure when required must be applied by the driver or guard; and as time is an element in this application there is the less danger of its being injuriously applied, even when extended to the limit of sledging the train, or stopping all the wheels. This power of application is however necessary, as the same amount of friction could not be applied with security to the train by the force of the spring, without incurring risk in the breakage of the wheels or axles.

The following are the particulars of the experiments made upon the East Lancashire Railway, to ascertain the retarding power of Mr. Newall's break, in stopping railway trains. The train in each case consisting of 10 carriages, besides the engine and tender, with a gross weight of 88 tons, including the engine and tender.

No. of Experiment.	Descending Gradient.	Speed of Train when Breaks were applied.	Distance run after Breaks were applied.	Remarks.
1	1 in 532	38 miles per hour	218 yards	Rails moist & slippery
2	Level	33 " "	100 "	Bury, rather doubtful
3	1 in 38	45 " "	430 "	Accrington Incline
4	1 in 40	48 " "	371 "	Ditto ditto
5	Level	48 " "	192 "	Blackburn, two wheels sledged
6	Level	40 " "	138 "	Ditto, five do.
7	Level	50 " "	310 "	Ditto
8	Level	42 " "	620 "	Blackburn, 3 wheels sledged
9	Level	40 " "	800 "	Ditto

The experiments 1 to 7 were made with 8 of the carriages in the train fitted with Newall's break, besides the ordinary tender break; and the experiments 8 and 9 were made with ordinary breaks, 2 carriages being fitted with them in No. 8, and 1 in No. 9.

In the experiments 5 to 9, more particular care was taken to ascertain the speed by time and distance, and the moment at which the breaks were to be applied was marked more definitely by the explosion of a detonating signal at the point fixed.

The general result of these experiments appears very favourable to Mr. Newall's break, as to the efficiency of its retarding power compared with those in ordinary use. At 40 miles an hour, upon a level, with the improved break the train was brought up in a distance of 138 yards, but with the ordinary breaks, at 42 miles an hour, 620 yards was run over before the train could be stopped; or in other words a railway train can be stopped in one-fourth the distance.

Another plan has been proposed by Mr. Samuel Newton, of Stockport, for attaining the same object of putting on the breaks in the train by self-acting means. To accomplish this a friction-wheel, 2½ feet diameter and 10 inches broad, is proposed to be fixed on the centre of each axle; this friction-wheel is to be surrounded with an ordinary clamp break, such as is generally used in connection with cranes, consisting of an expanding steel ring, lined internally with wood. One end of this break-ring is fixed to the carriage frame, and to the other end is attached the short arm of a lever, so that when the long arm of the lever is raised the ring is by this motion enlarged a little in diameter to allow the friction-wheel to revolve within it without being touched. The long arm of the lever from the front axle approaches that from the hind axle, and both meet under the centre of the carriage; here the levers are joined by a bolt with a slide, so that they may rise and fall together. A weight is then attached, the tendency of which is to depress both levers, and to cause their respective short arms to collapse each break-ring tightly round the friction-wheel, and thus arrest its revolution, and with it that of the axle and wheels. This is proposed to be the arrangement for every carriage, the weight on the levers between each pair of wheels being about 120lbs. By force of gravity the breaks will apply themselves, and the power to be exerted must be

for the purpose of taking them off. This is proposed to be done by the pull of the engine, by means of a metal rod with joints, which passes under all the carriages in a train, and is placed in connection with the weighted levers. The first end of this rod is to be joined to the tender, and when the engine starts it will draw out the rod so as to lift up all the levers, and thus release the breaks from the friction-wheels, and keep them clear so long as the engine continues its tension upon the draw-bar. By this arrangement it is contemplated by the inventor, that in order to stop the train it will simply be necessary to arrest the speed of the engine, and that the draw-bar will then slide backwards by the action of the weights, which will at the same time depress the levers and apply the breaks.

In another plan for accomplishing a similar object, recently proposed by Mr. Alfred Molson, of London, the application of the breaks is proposed to be effected by means of a break-bar sliding longitudinally under each carriage, acting on the levers of the break-blocks, and projecting at each end of the carriage as far as the buffers, so as to come in contact with the ends of the break-bars of the adjoining carriages.

On a check being given to the engine, and its speed being retarded by applying the break to the tender, the hindmost carriages of the train will press on those preceding them, and the springs of the ordinary buffers giving way, the train will be thereby shortened some inches while the break-bar of each carriage remaining of its original length, and resisting the advance of the carriages behind, it will follow that the last two or three carriages will have the breaks put on before even the guard in the van has turned the handle of his break.

The two latter plans not having been yet tried, except in models, no practical results can be given, and they have been named with the view of bringing under the consideration of the members the important subject of the prevention of collisions of railway trains, by increasing the retarding power of the breaks.

A large working model of Mr. Newall's Railway Break was exhibited and shown in action; also a model of Mr. Newton's Break.

The Chairman observed that he had been much struck with the very prompt and instantaneous action of Mr. Newall's break when he wit-

nessed the recent trial of it upon the East Lancashire Railway; it would be an important auxiliary in preventing collisions if the means were always at hand for stopping the trains in so short a distance, and this break appeared well suited for the purpose, if it did not get out of order, and was not too expensive.

Mr. PERRING said he had observed the working of these breaks during three months' daily work on the East Lancashire Railway, in which time they had travelled 9400 miles between Manchester and Colne, with 4811 stoppages, being stopped at a station every two miles. There had been no case of the breaks being out of order during this trial, and they had been found to work quite satisfactorily and efficiently; he had recently examined them and found the whole apparatus was standing well; the break-blocks were worn down much less than usual in the time, on account of the greater number of them that were in action at once, and the wheel tires were found to have worn only about 1-10th of an inch in the time, as shown by the templates of the tires exhibited. There were three trains running with these breaks on the East Lancashire Railway, and he should be glad to show them in operation to any of the Members who might wish to examine their action.

The CHAIRMAN inquired what would be the expense of applying Mr Newall's plan to the present railway carriages?

Mr. NEWALL replied that the cost of applying it to the present break-carriages would be about £9 per carriage; but he did not think the extra cost would exceed £5 per carriage in the case of building new stock.

The CHAIRMAN observed that the principle of the break had certainly a great advantage in the promptness with which the breaks in the train could be all put on simultaneously, either by the guard or the engineman in the moment of emergency, as the springs had only to be released at the moment the breaks were required, and there was always plenty of time afterwards for drawing them up again. The break handle also gave the means of direct communication between the guard and the engineman, free from interruption.

He inquired what would be the cost of Mr. Newton's break? and how he proposed to provide for backing a train without causing the breaks to be put on? He did not see how that could be accomplished by his plan.

Mr. Newton replied that he thought the extra cost would not exceed £3 per carriage. When the train was backed there would be a means required for holding the draw-bars so as to prevent the breaks being put on, also to give the guard the means of putting on the breaks; the plan had not been completed yet in this respect, but he thought it was practicable to accomplish the object.

Mr. Dyer remarked that there would be a disadvantage in having a weight instead of a spring for acting on the break, as there would be the weight to be carried, and its action would not be so steady as a spring.

He proposed a vote of thanks to the Chairman for his paper, which was passed; and to Mr. Newall and Mr. Newton for the models they had brought before the meeting.

Mr. Cowper proposed a vote of thanks to the Council of the Royal Institution for their kindness in granting the free use of their Lecture Theatre for the meeting.

The motion was seconded by Mr. Jones, and passed.

The meeting then terminated.

The following paper, by Mr. Andrew J. Robertson, of London, was read at a previous meeting (see Proceedings, Institution of Mechanical Engineers, 1853, p. 72), but the publication has been delayed in consequence of the absence of the author from the country.

ON THE MATHEMATICAL PRINCIPLES INVOLVED IN THE CENTRIFUGAL PUMP.

In a paper by the writer at a former meeting (see Proceedings of the Institution of Mechanical Engineers, 1852, pp. 99 and 153), the action of Centrifugal Pumps with *straight arms* was investigated, and it was shown that there is a waste of power to the extent of 50 per cent. in consequence of the circular motion communicated to the water. In Mr. Appold's pump this source of loss is avoided to a certain extent by *curving the blades*, and the experiments conducted by the Jury of the Great Exhibition show a saving of 44 per cent. over the same pump

with straight arms. But as the action of these blades has been supposed to be that of a system of inclined planes, (an idea in which the writer concurred at one time,) it appears desirable that the subject should be brought forward again for the purpose of investigating the true cause of the efficiency of curved blades.

Whilst therefore the present forms a supplement to the former paper, it will be found that the theory of curved arms constitutes the general proposition of which that of straight arms is the particular case, consequently it will be more convenient to consider the subject generally, referring only to the former paper for the explanation of those details which it would be useless to repeat.

A Centrifugal Pump, then, in its most general form, may be considered as a bent pipe A, see Figs. 3, and 4, Plate 40, revolving round a suction pipe B as a centre, the plane of revolution being either horizontal or vertical, and the curve being wholly in the plane of revolution, as it will be evident from the sequel that no good purpose would be served by the pipe having a double curvature.

In Fig. 1, Plate 40, let RPT be the centre line of the arm or pipe revolving round S in the direction of the arrow, the sectional area of the arm being uniform throughout.

ST the radius of the suction pipe $= R_1$,

SR the radius of the circle described by the extremity of the arm $= R_2$,

$\alpha =$ the angular velocity,

$\theta =$ the angle PSX,

$r = f(\theta)$ the polar equation to the curve of the arm,

and $s =$ the length of the curve.

Let the sectional area of the pipe be constant and equal unity.

Then the weight of an elementary portion of the contained water is represented by its length;—which, taken with reference to the angle described by the radius vector, is $\frac{ds}{d\theta}$.

Since the element at P revolves in a circle of which the radius is SP, the centrifugal force is represented by*

$$\frac{\alpha^2}{g} \text{PS} \times \frac{ds}{d\theta} = \frac{\alpha^2}{g} r \frac{ds}{d\theta},$$

* Moseley's Mechanical Principles, Equation 108, page 125.

but by the principles of the differential calculus*

$$\frac{ds}{d\theta} = \sqrt{r^2 + \frac{dr^2}{d\theta^2}}.$$

Therefore the centrifugal force $= \dfrac{a^2 r}{g} \sqrt{r^2 + \dfrac{dr^2}{d\theta^2}}$ ......(1.)

This force acts in the direction SP, and in order to ascertain its effect in propelling the water along the pipe it must be resolved into two others,—one in the direction of the tangent to the curve—the other at right angles to it.

If PS represent the amount of the centrifugal force, as well as its direction, PQ will represent the force expended on the material of the pipe, and PY that which urges the water above it.

The perpendicular on the tangent of a polar curve is represented by†

$$\frac{r^2}{\sqrt{r^2 + \frac{dr^2}{d\theta^2}}},$$

$$\text{Hence PY} = \sqrt{\text{SP}^2 - \text{SY}^2} = \sqrt{r^2 - \frac{r^4}{r^2 + \frac{dr^2}{d\theta^2}}} = \frac{r\frac{dr}{d\theta}}{\sqrt{r^2 + \frac{dr^2}{d\theta^2}}}$$

The Force along PY : Centrifugal force : : PY : PS,

$$\text{or Force along PY} : \frac{a^2 r}{g}\sqrt{r^2 + \frac{dr^2}{d\theta^2}} : : \frac{r\frac{dr}{d\theta}}{\sqrt{r^2 + \frac{dr^2}{d\theta^2}}} : r$$

Therefore Force along PY $= \dfrac{a^2 r}{g} \dfrac{dr}{d\theta}$ ......(2.)

Since the sectional area has been supposed equal throughout the length of the arm, the water must, in order to preserve its continuity, move with the same velocity at all points; therefore the whole force urging the water as one mass along the arm, is the sum of all the forces acting on the individual elementary portions.

Now the sum of all the forces represented by Equation (2) is the definite integral of that equation between the limits $r = R_2$ and $r = R_1$.

* Hall's Differential and Integral Calculus, page 172.

† Hall's Differential and Integral Calculus, page 171.

Therefore the whole force producing a flow through the arm

$$= \frac{\alpha^2}{g} \int_{R_1}^{R_2} r \frac{dr}{d\theta} = \frac{\alpha^2}{2g} \left(R_2^2 - R_1^2\right) \text{.........} (3.)$$

or it is precisely the same as if the arm were straight.

The effect of a varying section of a pipe will be discussed afterwards; but, supposing the section to be uniform, the water contained between two consecutive blades of Mr. Appold's Pump (see Fig. 6) is in exactly the same condition as that contained in this pipe. It must consequently be evident that until the force urging the water outwards be greater than the pressure of the working head (the height of the discharge above the surface of the water to be raised), no motion outwards can take place.

Whatever be the angular velocity, therefore, there is always a certain head which will be just supported and no more, and the cause of its being supported is centrifugal force.

If, then, whilst the velocity remains constant the head be diminished, a flow will take place; and there can be no reason for supposing the mode of action to change and become that of an inclined plane. It must, therefore, be admitted to be centrifugal action throughout, and the velocity through the arm is that due to the excess of the centrifugal force above the working head, and is equal to

$$\sqrt{2g\left\{\frac{\alpha^2}{2g}\left(R_2^2 - R_1^2\right) - h\right\}} = \sqrt{\alpha^2\left(R_2^2 - R_1^2\right) - 2gh}$$

Let αR_2 the velocity of the outer extremity of the arm be V_2
αR_1 ditto inner ditto ditto V_1

and let $2gh = v^2$

then the area of section being unity, the discharge per second is

$$\sqrt{V_2^2 - V_1^2 - v^2}.$$

The direction in which the water would move when it leaves the arm, would, if there were no circular motion, be that of the arm itself, or a tangent to the curve at the extremity.

Let SR, in Fig. 1, be the arm,

BRO a tangent to the curve of the arm at R;

Let BR represent the velocity of discharge,

and RD a tangent to the circle described by R represent the tangential velocity,

then RC is the actual motion in space in magnitude and direction.

$$RC^2 = RB^2 + BC^2 - 2\ RB\ .\ BC \cos.\ RBC$$

$$= \left(V_2^2 - V_1^2 - v^2\right) + V_2^2 - 2V_2\sqrt{V_2^2 - V_1^2 - v^2} \cos.\ RBC.$$

Let the angle SRO, which the radius vector makes with the tangent to the curve, be ϕ,

then the angle RBC $= \frac{\pi}{2} - \phi$, and $\cos.\left(\frac{\pi}{2} - \phi\right) = \sin\ \phi$

Therefore $RC^2 = 2V_2^2 - V_1^2 - v^2 - 2V_2\sqrt{V_2^2 - V_1^2 - v^2} \sin.\ \phi$

Then the numbers of units of work expended upon communicating to the water the velocity with which it leaves the pump, is

$$U_1 = \frac{\left(2V_2^2 - V_1^2 - v^2 - 2\ V_2\sqrt{V_2^2 - V_1^2 - v^2} \sin.\ \phi\right)\sqrt{V_2^2 - V_1^2 - v^2}}{2\,g}$$

and the number of units of work expended on raising the water delivered to the height of discharge, is

$$U_2 = \frac{v^2}{2g}\sqrt{V_2^2 - V_1^2 - v^2}$$

Therefore the whole power

$$U_1 + U_2 = \frac{\left(2V_2^2 - V_1^2 - 2V_2\sqrt{V_2^2 - V_1^2 - v^2} \sin.\ \phi\right)\sqrt{V_2^2 - V_1^2 - v^2}}{2\,g} \quad \text{..........(4).}$$

The useful effect $= \frac{v^2}{2g}\sqrt{V_2^2 - V_1^2 - v^2}$

Therefore the ratio of useful effect to the power expended is

$$\frac{v^2}{2\ V_2^2 - V_1^2 - 2\ V_2\sqrt{V_2^2 - V_1^2 - v^2} \sin.\ \phi} \quad \text{..........(5)}$$

When $\phi = 0$, or the arm terminates in the direction of the radius, and if V_1 be considered so small that it may be neglected, the expression becomes

$$\frac{v^2}{2\ V_2^2}$$

which is the ratio given in the former paper for a pump with straight arms.

Equation (5) is evidently a maximum, or the duty is greatest, when $\sin.\ \phi$ is a maximum, or when $\phi = 90°$ the expression then becomes

$$\frac{v^2}{2\ V_2^2 - V_1^2 - 2\ V_2\sqrt{V_2^2 - V_1^2 - v^2}}$$

the value of which evidently increases as v diminishes, or the economy is greater the lower the lift.

It appears, then, that in order to get the greatest ratio of useful effect, the angle ϕ must be 90°,—that is, the arm must be bent back until the tangent at its extremity coincides with the tangent to the circle described by it. Hence the velocity of exit is directly opposed to the tangential velocity, and consequently the actual velocity of the water is the difference between the two velocities.

If $v = 0$, or there be no head, and the diameter of the suction pipe be so small that V_1 may be neglected, the velocity of discharge equals the tangential velocity, and the water drops off at rest.

We have here, then, an explanation of the economy arising from the use of *curved blades*. When the arms are straight the loss can never be less than one-half the power, because one-half is absorbed by the tangential velocity, and the only means of raising the per-centage of useful effect, is by *diminishing* the *velocity of discharge*. But with *curved arms* it is quite the reverse; the *greater the velocity* of discharge the less is the difference between it and the tangential velocity.

It is necessary to remark here, that in this inquiry it has been assumed that only that water which is between the blades has a rotatory motion, and that the centrifugal force, and consequently the column balanced by it, are less than if the blades extended completely to the centre. Now this is not exactly true, for it is evident that a certain amount of rotatory motion will be communicated to the water in the entrance by contact with the sides, and that part of the water which is revolving. The amount of this motion it is impossible to determine, but it will probably be proportionately greater the less the velocity through the pump.

The following table is calculated to show the variation of effect produced by a variation in height of lift—supposing the direction of the arm at the extremity to be a tangent to the circle described by it, V to be neglected, and the velocity of the extremity of the arm to be 32·2 feet per second—

HEIGHT OF LIFT.	PER-CENTAGE OF EFFECT, POWER BEING 100.
3 feet	93
6 ,,	90
9 ,,	$83\frac{1}{2}$
12 ,,	75
15 ,,	63
16 ,,	No delivery.

Although, as we have seen, the nature of the curve of the arm is a matter of no consequence as far as the principle is concerned, it must be more important in practice.

The form which would cause the water to move in a straight line from the centre to the circumference, would evidently be the best. This can be given only when there is no lift, that is when the velocity of delivery is equal to that of the end of the arm; but the curve which suits this case will give the nearest approximation at all other velocities of delivery.

Let PO, in Fig. 2, be a portion of the arm revolving round the centre S,—

let the velocity of flow through the arm be uniform and equal to c,—

α being the angular velocity of the pump,

$\alpha\ r$ is the actual velocity of the point P.

Then if PO bear the same proportion to PR (the portion of the circle described by P round S), that the velocity c does to the velocity of P;—the particle of water which at the commencement of the motion was at O, will reach P at the same instant that P reaches R,—that is, the particle at O will have moved through space along the line OR.

Let PY be a tangent to the curve of the arm,

the angle SPY $= \varphi$

then PT $=$ PO sin. $\varphi =$ PS sin. PST.

But the angle PST may be indefinitely diminished, and then the ratio of the line to the arc becomes one of equality; so that

PO sin. $\varphi =$ PS $\delta\theta$, when $\delta\theta$ is the differential of the arc.

$$\text{Then make PO} : \text{PS}\ \delta\theta :: c : \alpha\, r$$

$$\text{or } \delta s : r\delta\theta :: c : \alpha\, r$$

$$\therefore \frac{\delta s}{\delta\theta} = \frac{ds}{d\theta} = \frac{c}{\alpha}$$

whence by integration $s = \frac{c}{\alpha} \theta$ .... (7).

$$\text{Therefore } \frac{ds}{d\theta} = \sqrt{r^2 + \frac{dr^2}{d\theta^2}} = \frac{c}{\alpha}$$

$$\text{whence } \frac{dr}{d\theta} = \sqrt{\frac{c^2}{\alpha^2} - r^2} \text{ and } \frac{d\theta}{dr} = \frac{1}{\sqrt{\frac{c^2}{\alpha^2} - r^2}}$$

$$\text{Therefore } \theta = \sin.^{-1} \frac{r\,\alpha}{c}$$

and $r = \frac{c}{\alpha} \sin. \theta$ .... (8)

which is the equation to the curve.

This differs from the spiral of Archimedes, as the equation to that curve is $r = m\,\theta$.

From equation (8) we have $\sin. \theta = \frac{\alpha\, r}{c}$ or $\theta = 90°$ when $c = \alpha\, r$, that is when the velocity of discharge is equal to the velocity of the arm.

In this case we find from (7) that $s = \frac{c}{\alpha} \frac{\pi}{2} = r \frac{\pi}{2}$ or the length of the arm is a quadrant of the circle described by the extremity.

Hitherto the sectional area of the arm has been supposed constant; —the next question for examination is what effect is produced by a variation of the section.

A *solid* of the form of the water contained in an arm of variable section, would have a centrifugal force dependent upon the position of the centre of the gravity;—but it is evident that the column which the centrifugal force of the *water* will balance, will be the same whether the section be uniform or variable, upon the same principle that the pressure per square inch produced by a vertical column is independent of any variation in the section of that column, and dependent only on its height.

It follows therefore that the column which is available for the production of the velocity of discharge, namely, the difference between the column representing the centrifugal force, and the height of the orifice of discharge above the surface of the water in the cistern, is the same, whether the section of the arm be constant or variable.

If the section diminishes towards the outer extremity, the velocity will increase; if the section increases, the velocity will diminish. But as the velocity produced by a given column can only be that due to the height of the column, it must in the first instance be considered as divided into two parts,—one producing the velocity with which the water must be added at the entrance of the pipe, the other producing the acceleration;—in the latter case the water is dragged through the entrance with a velocity greater than the ultimate velocity, and loses it in its passage through the pipe by communicating in its turn excessive velocity to the water entering. There appears therefore to be no advantage in principle in giving to the arm a variable section.

In corroboration of this view of the subject, the experiments of Venturi may be appealed to. It is well known that when a conical pipe, as A B in Fig. 5, was attached to an orifice in a vessel kept constantly full, the discharge was due to the head of water above the centre of the pipe and the area of the orifice B. But when a diverging conical pipe B C was added, the discharge was considerably increased. This increase of delivery has been attributed to the attraction of the sides of the pipe for the water, but this is a cause wholly inadequate to the effect. It is clear that whatever be the velocity of a particle at B, it is diminished when it comes to C in the same proportion as the sectional area is increased. But no effect can be produced without a cause: some retarding force must therefore have been in operation.

Suppose the velocity to continue the same;—the portion of water at B, (section-lined) becomes thinner as it advances along the expanding pipe to C, and according to the supposition, the continuity of the water will be broken, and a space left between all the elementary portions into which the water may be supposed to be divided. But the space so left (shown white) would be a vacuum, and consequently the pressure of the atmosphere would be exerted to propel the particles at B faster, and check the velocity of those in advance.

It must therefore be evident that the effect will be that the continuity of the water is preserved, and the motion of the particles at B increased considerably beyond what it would otherwise have been.

For the production of this effect it is necessary that the pipe be of such a material that there may at least be no repulsion between it and the water, as in that case the water would not flow in a full stream;—and it must moreover be evident that if it were not for friction, the velocity of discharge at C would be precisely the same as if the orifice B had had the same size, and there had been no additional conical pipe. In practice friction has a considerable influence, and the delivery is accordingly less than that due to the head and the area at C.

From Equation (6) it appears that, *ceteris paribus*, the economy is greater the smaller V is; that is, the smaller the diameter of the suction pipe. But if this pipe were made very small, power would be lost in communicating to the water an unnecessary velocity, and therefore it follows that the most advantageous proportion is when the area of the suction pipe at the entrance of the arm is just equal to that of the arm, and that the per-centage realized with one arm will be greater than when there are several. It also follows that it is more advantageous to increase the diameter of the pump than the angular velocity.

In Mr. Appold's Pump the diameter of the suction pipe bears a large proportion to the diameter of the disc, being as much as one half. It will likewise be evident from the drawing, Fig. 6, of this pump, that the channel formed by two contiguous blades A A, does not terminate at R in the direction of a tangent to the circle described by the extremity, but makes a considerable angle with the tangent. It may therefore be expected that a higher per-centage may yet be realized than is shown by the experiments of the Jury of the Great Exhibition.

INDEX.

IMPROVED RAILWAY CHAIR.

Fig. 1. *Joint Chair. Inner side.*

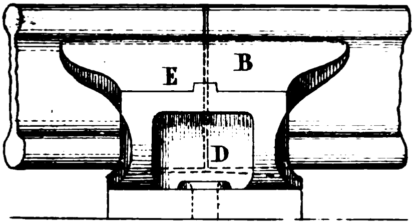


Fig 4. *Intermediate Chair.*

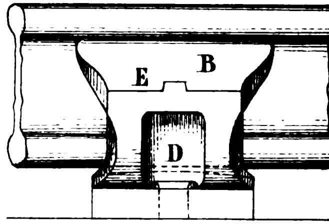


Fig 2. *Joint Chair. Outer side.*

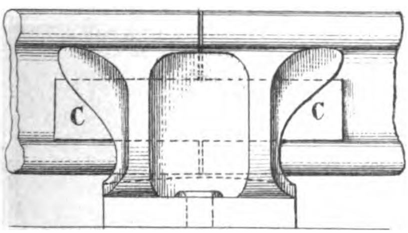


Fig. 5. *End View.*

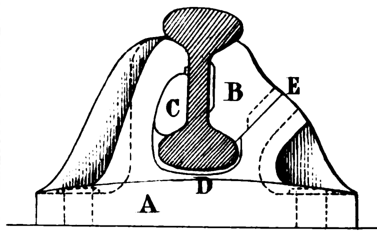


Fig. 3. *Joint Chair. Plan*

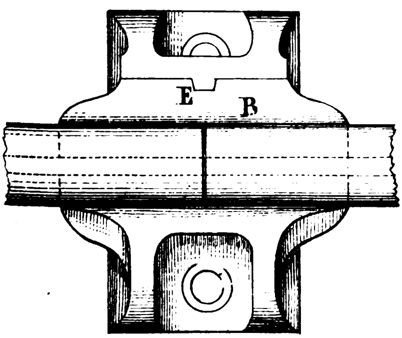


Fig. 6. *Chair with Iron Key.*

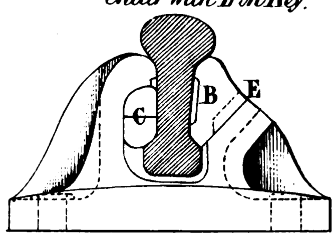
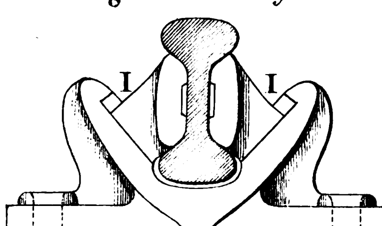


Fig 7. *Iron Key to Fig 6.*

Fig. 8. *Double-Wedge Chair.*



Scale 1/6th. 0 3 6 9 12 *Inches*

IMPROVED RAILWAY CHAIR.

Experiments on the Strength of Chairs.

Fig. 9. Intermediate Chair.

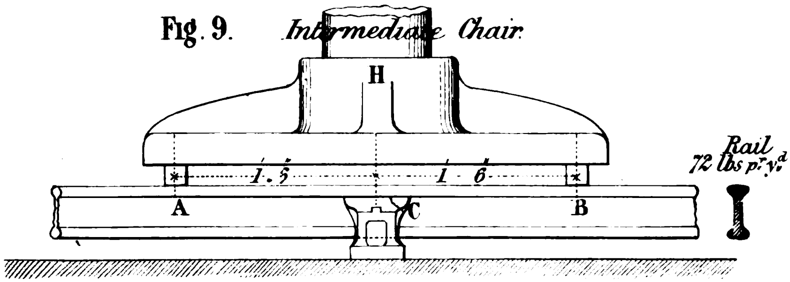


Fig. 10. Joint and Intermediate Chairs.

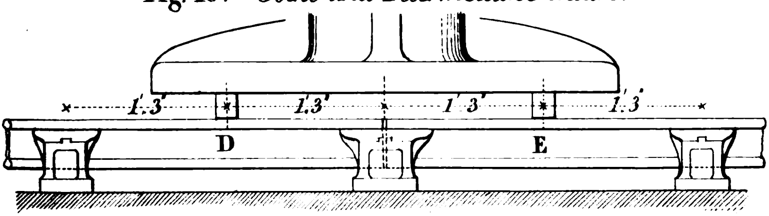
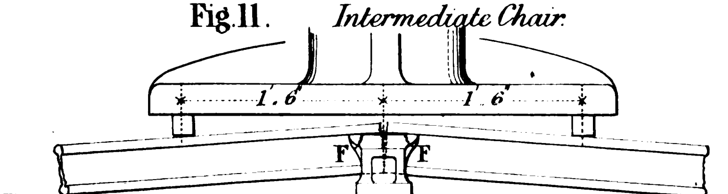
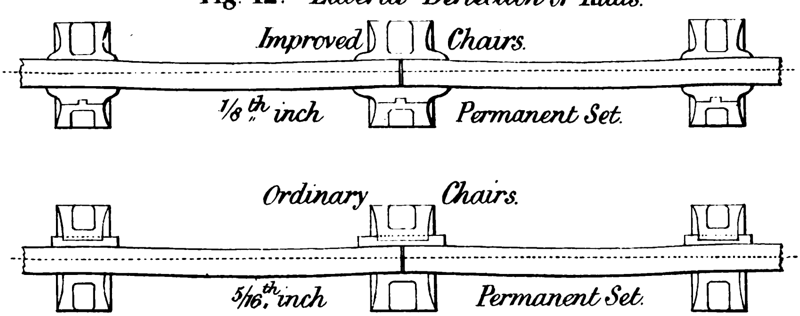


Fig. 11. Intermediate Chair.



Rail broken at 60 Tons pressure.

Fig. 12. Lateral Deflection of Rails.



Scale 1/18th size.

IMPROVED RAILWAY CHAIR

Permanent Way,
with Longitudinal Sleepers under the Joints.

Fig. 13. *Side Elevation.*

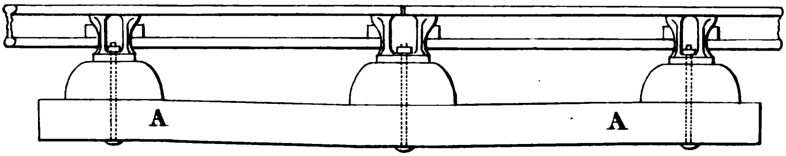
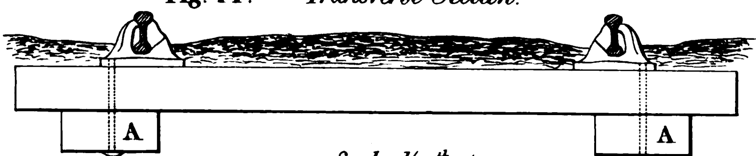


Fig. 14. *Transverse Section.*

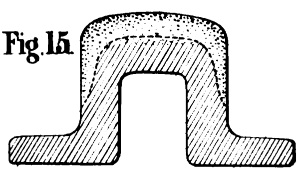


Scale 1/24th size

IRON MANUFACTURE

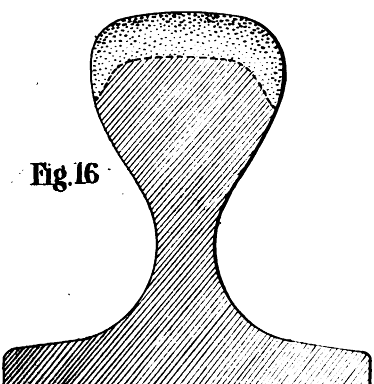
Rails with Hardened Iron Tops.

Fig. 15.



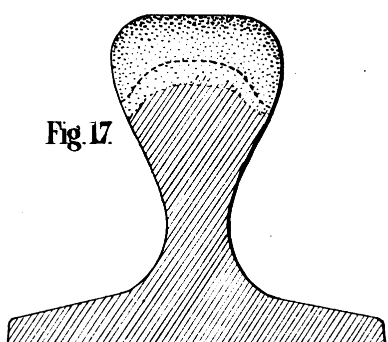
Hardened Scotch Iron.

Fig. 16.



Consett.

Fig. 17.



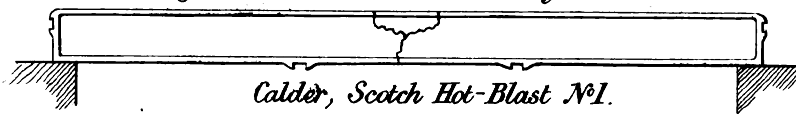
Cyfarthfa.

Scale ½ size.

Experiments on the Transverse Strength of Cast Iron Girders.

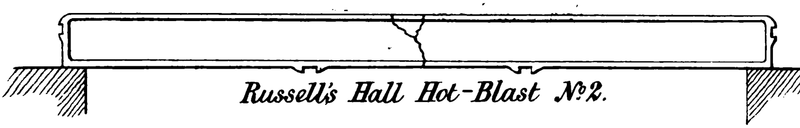
1st Ordinary Cast Iron.

Fig. 1. *34 Tons Breaking strain.*



Calder, Scotch Hot-Blast No. 1.

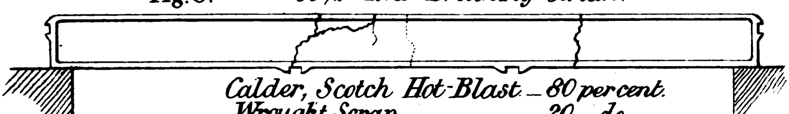
Fig. 2. *33¼ Tons Breaking strain.*



Russell's Hall Hot-Blast No. 2.

2nd Toughened Cast Iron

Fig. 3. *60½ Tons Breaking strain.*

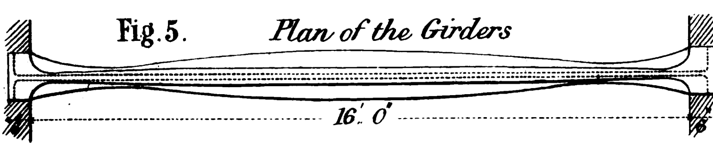


Calder, Scotch Hot-Blast — 80 per cent.
Wrought Scrap 20 do.

Fig. 4. *52½ Tons Breaking strain.*

Russell's Hall Hot-Blast 38 per cent.
Prior Field Hot Blast 48 do.
Wrought Scrap 14 do.

Fig. 5. *Plan of the Girders*



Scale 1/54th size

Fig. 6. *Transverse Section of Girders*

Double Scale

CUGNOT'S LOCOMOTIVE ENGINE, 1769.

Fig 1. *Elevation.*

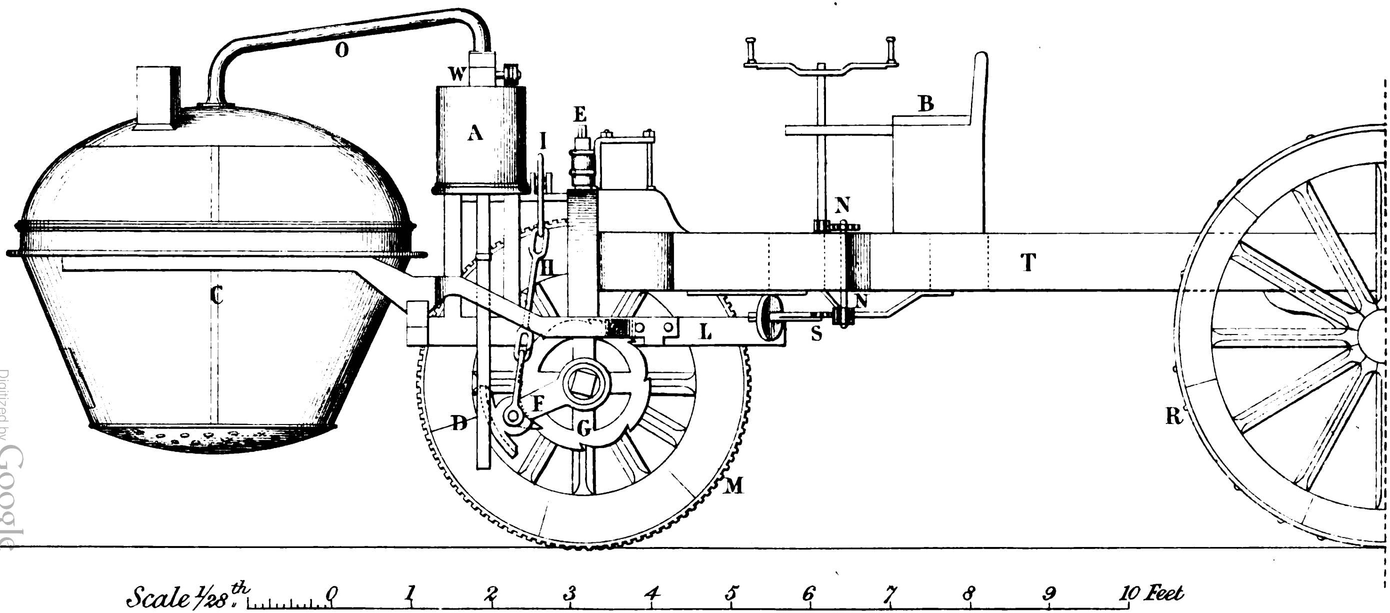
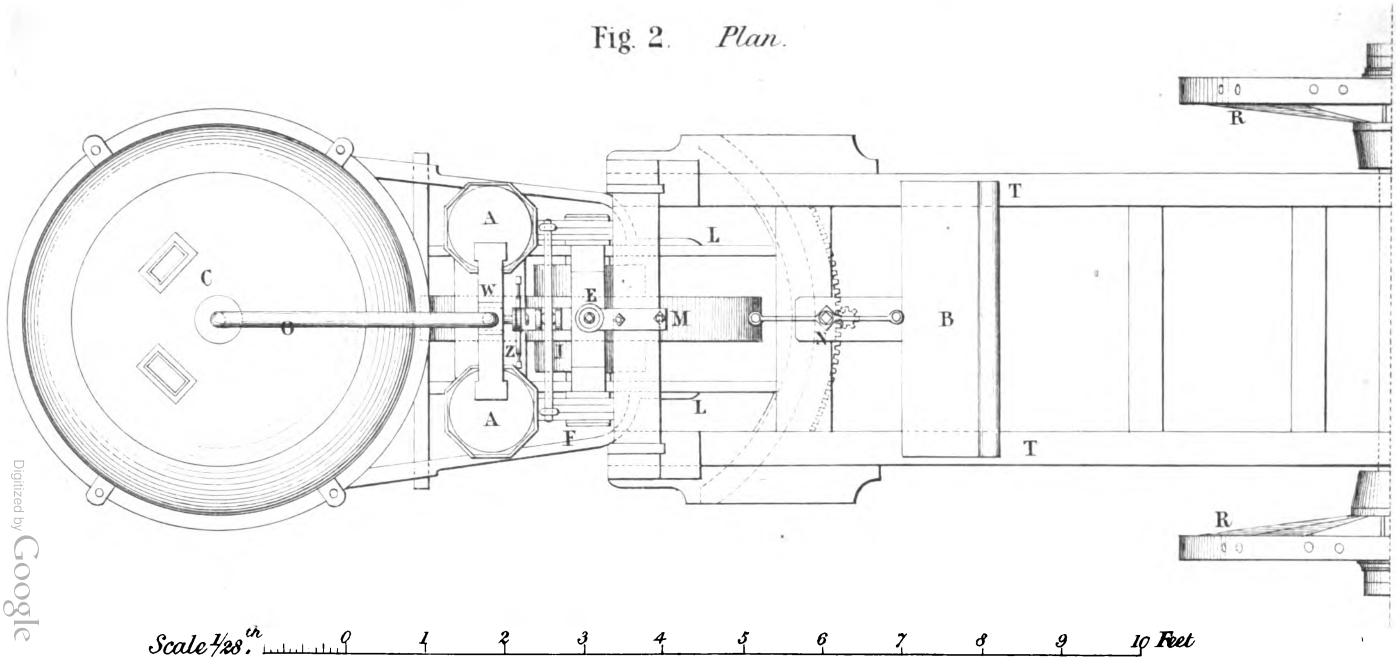


Plate 6.

CUCNOT'S LOCOMOTIVE ENGINE, 1769.

Fig. 2. *Plan.*



(Proceedings Inst. M.E. 1853, Page 31.

Plate 7.

CUGNOT'S LOCOMOTIVE ENGINE, 1769.

Fig. 3. *Longitudinal Section.*

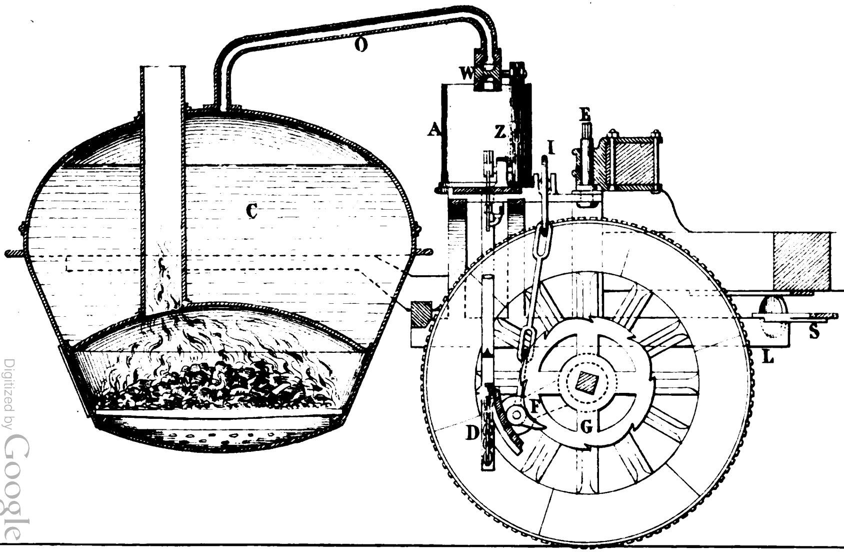
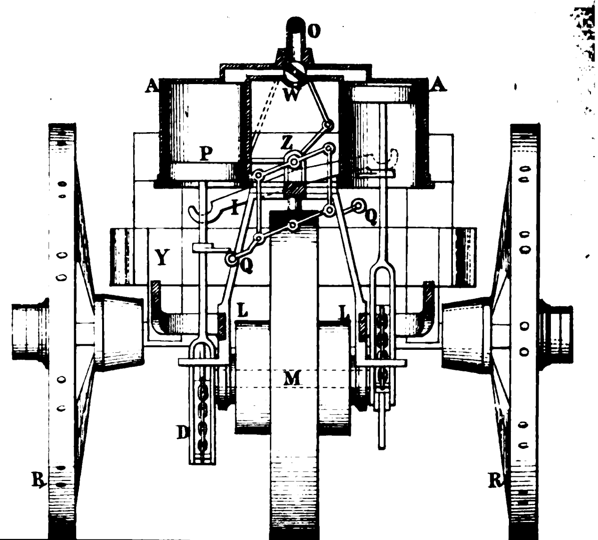


Fig. 4. *Transverse Section.*



Scale 1/28th. 0 1 2 3 4 5 6 7 8 9 10 Feet

SPONGE AXLE-BOX.

Plate 8.

Engine Axle-Box for Leading & Trailing Wheels.

Fig. 1.
Longitudinal Section

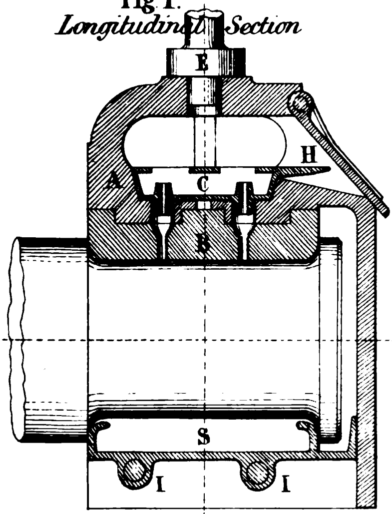
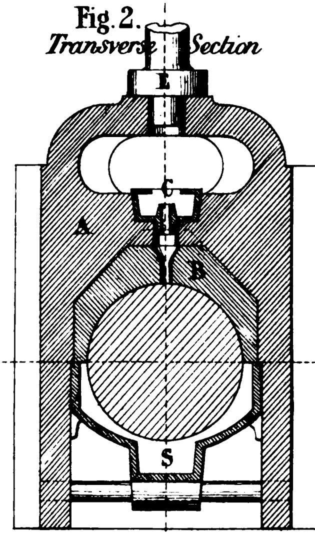


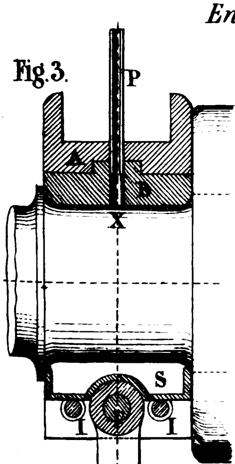
Fig. 2.
Transverse Section



Scale 1/5th 0 3 6 9 12 *Inches*

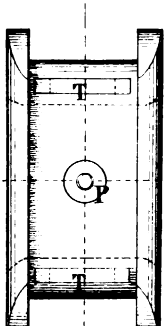
Engine Axle-Box for Driving Wheels.

Fig. 3.



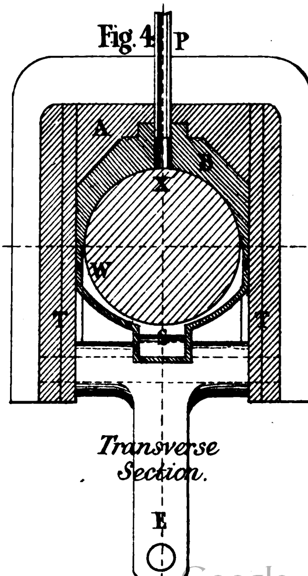
Longitudinal Section

Fig. 5.



Plan

Fig. 4.

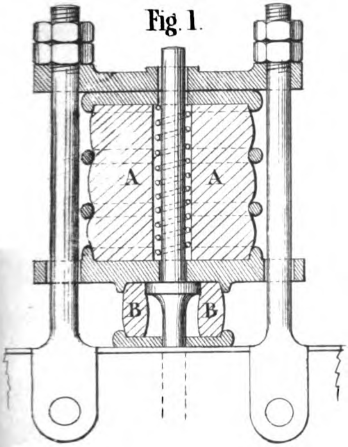


Transverse Section.

INDIA-RUBBER SPRINGS.

Engine Bearing Spring

Fig. 1.



Triple Bearing Spring

Fig. 2.

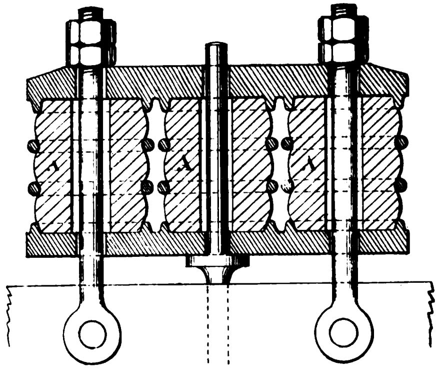


Fig. 3. Waggon Bearing Spring

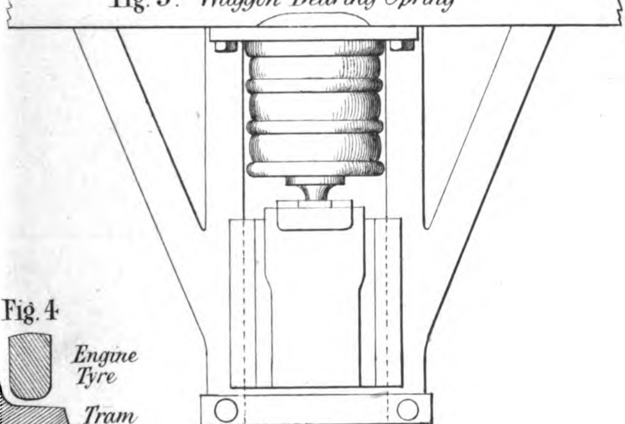


Fig. 4.

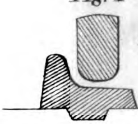


Fig. 5.
Engine Draw Spring

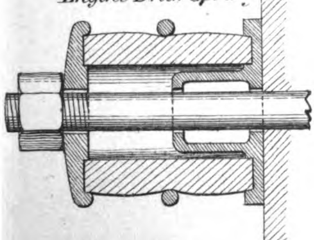
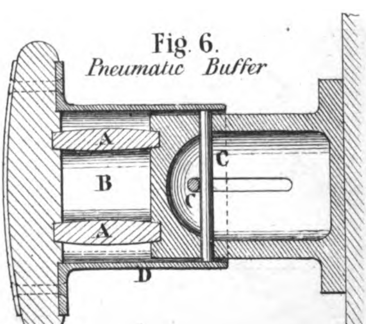


Fig. 6.
Pneumatic Buffer



Scale 1/10th 0 6 12 18 24 Inches

(Proceedings Inst. M.E. 1853. Page 47.)

INDIA RUBBER SPRINGS.

Fig. 7.
Hydro-Pneumatic Engine Spring.

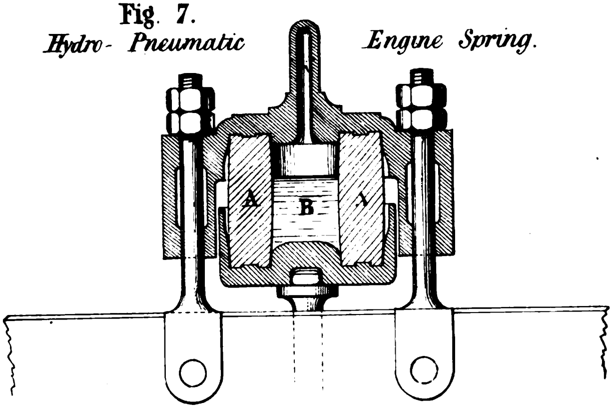


Fig. 8. *Improved Hydro-Pneumatic Spring*

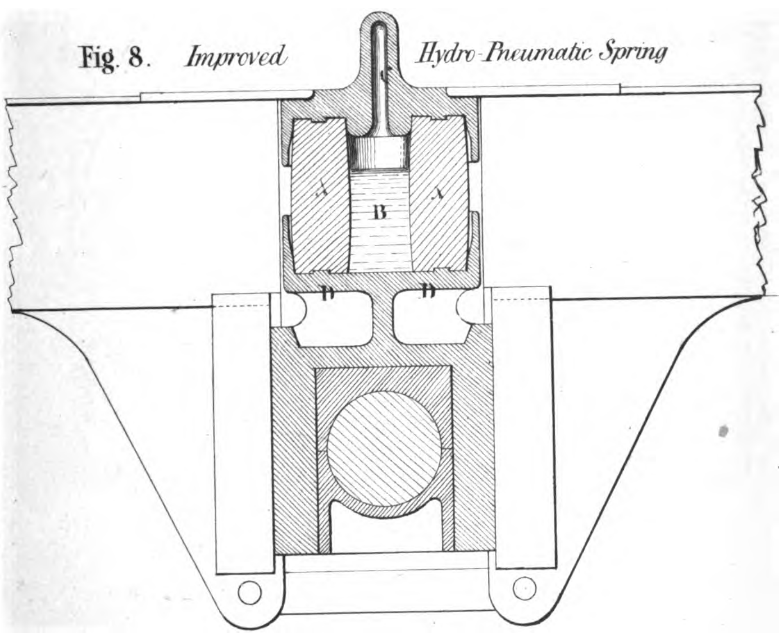
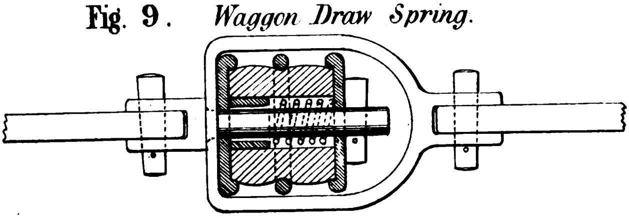


Fig. 9. *Waggon Draw Spring.*



Scale 1/10th. 0 6 12 18 24 *Inches*

ADAMS' CARRIAGE AXLE-BOX

Fig. 1.

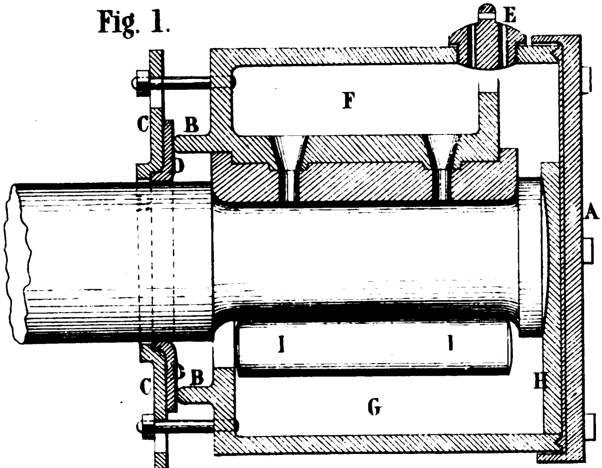


Fig. 2.

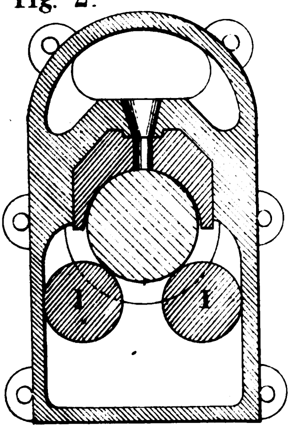


Fig. 4.

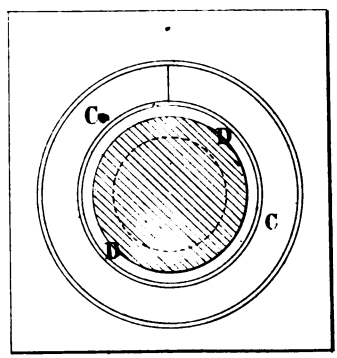
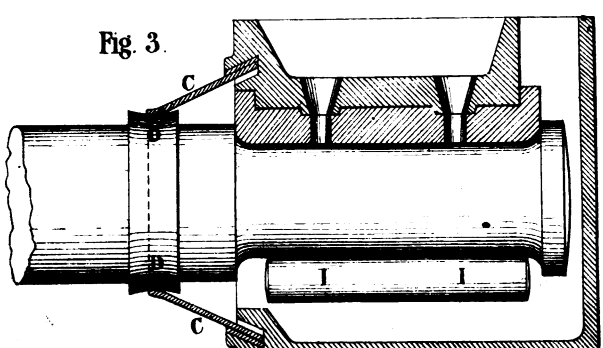
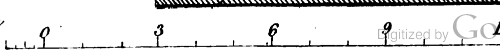


Fig. 3.



Scale 1/5th



ADAMS' CARRIAGE AXLE-BOX.

Fig. 5.

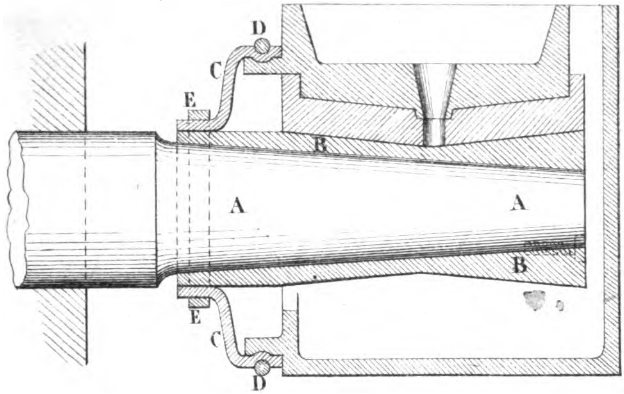


Fig. 6.

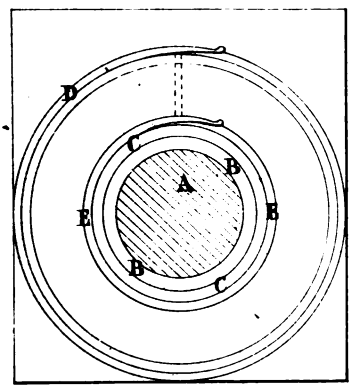


Fig. 8.

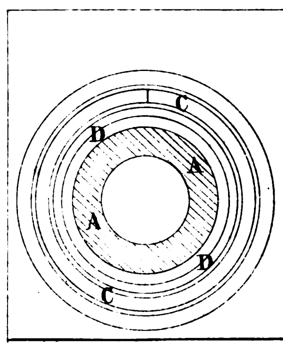
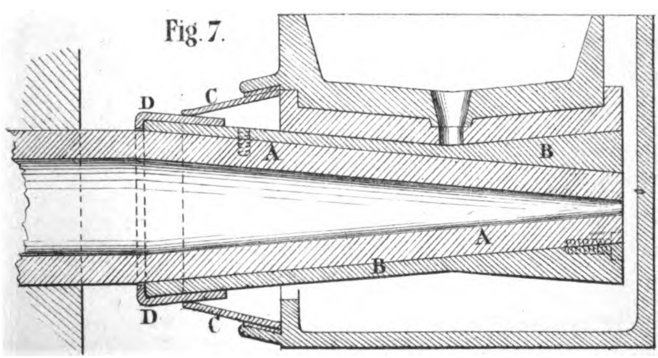


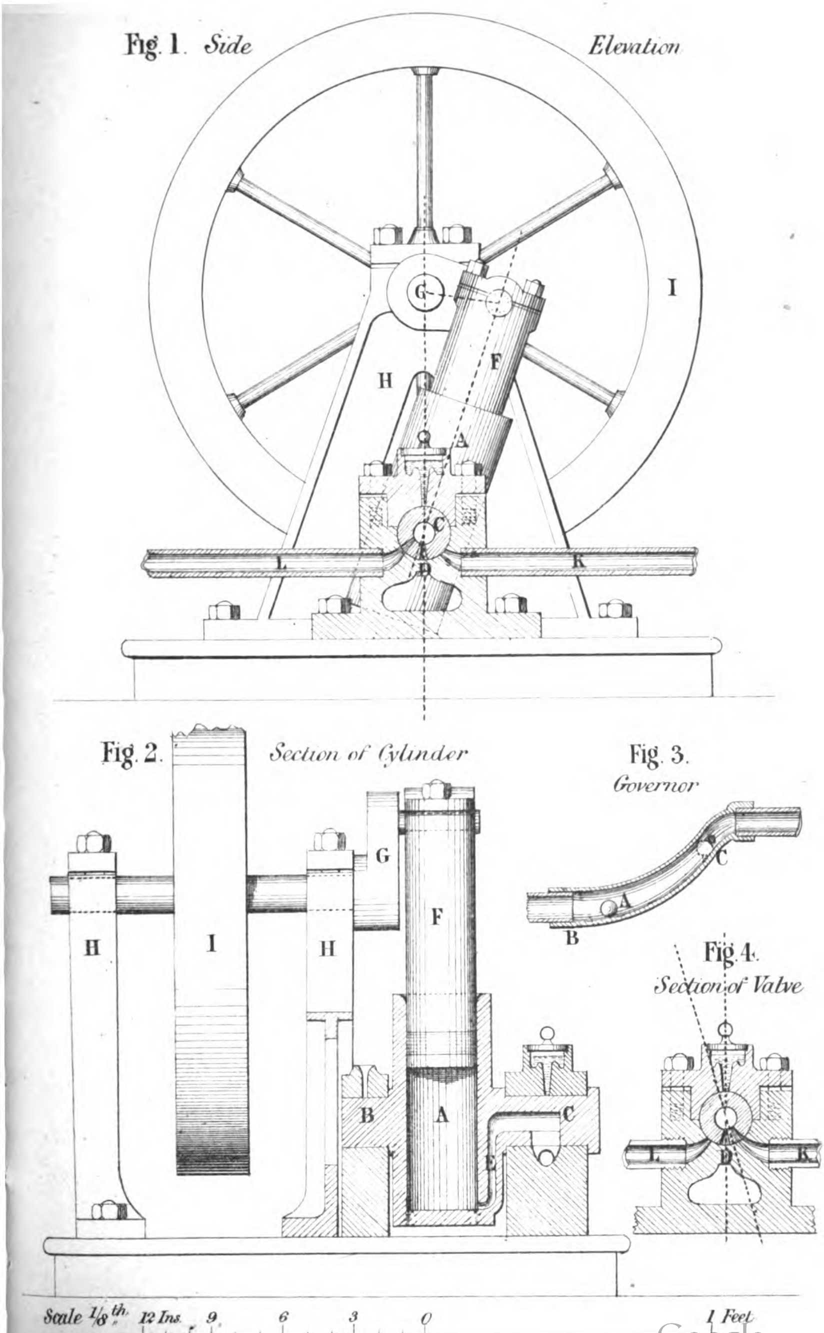
Fig. 7.



Scale 1/5th 0 3 6 9 12 *Inches*

(Proceedings Inst. M.E. 1853. Page 61.)

PORTABLE STEAM ENGINE.



(Proceedings Inst. M.E. 1853, Page 69)

PORTABLE STEAM ENGINE.

Fig 5

Elevation of Engine and Boiler

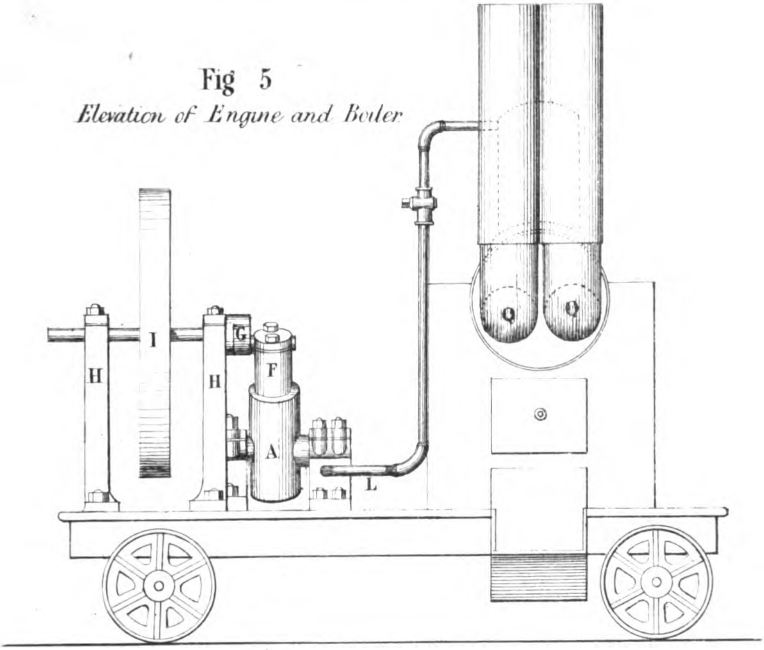
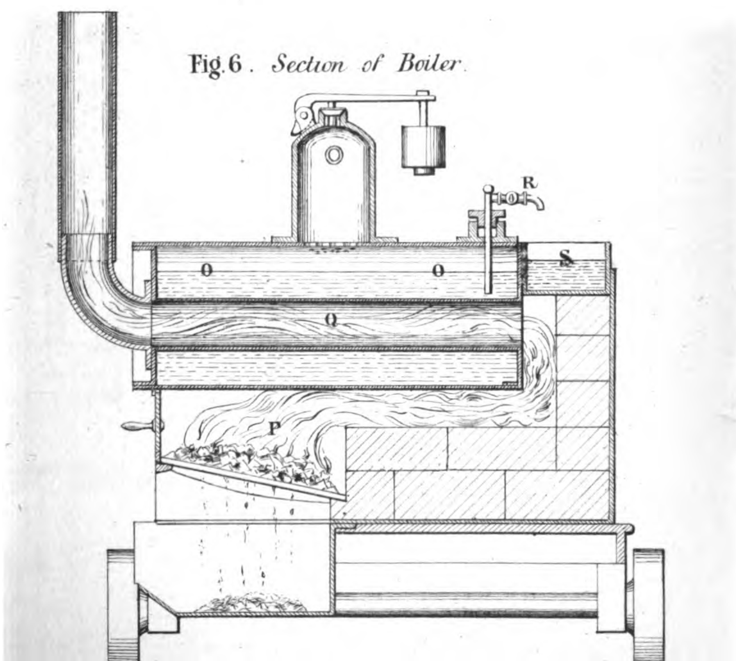


Fig. 6. *Section of Boiler.*



Scale 1/16th 0 1 2 3 *Feet*

Fig. 1. *Watt's Centrifugal Governor*

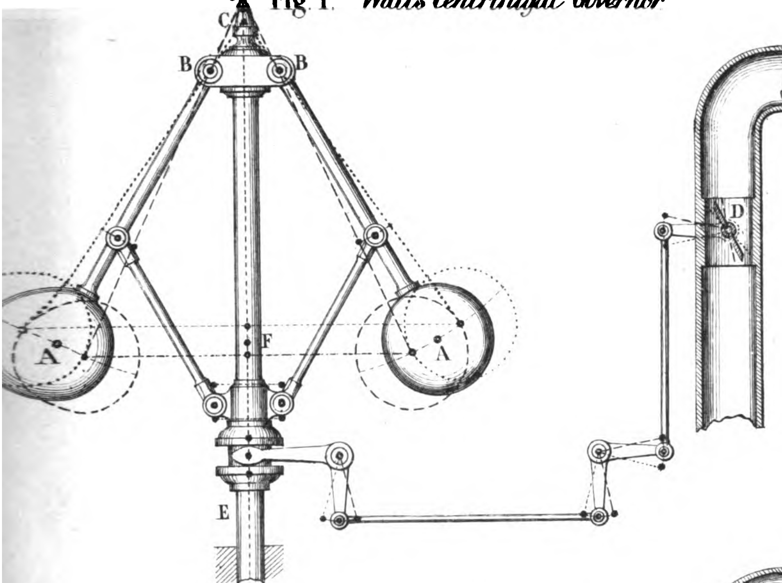
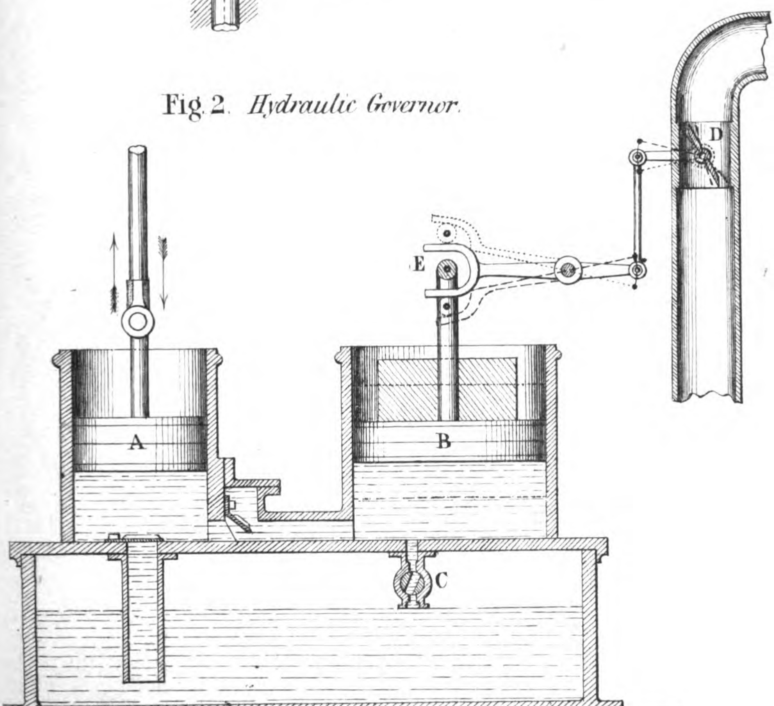


Fig. 2. *Hydraulic Governor.*



Scale 1/15th 0 1 2 *Feet*

(Proceedings Inst. M.E. 1853, Page 76.)

STEAM ENGINE GOVERNORS.

Plate 16.

Hick's Fly Governor.

ig. 3.

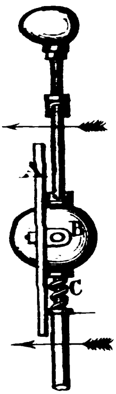
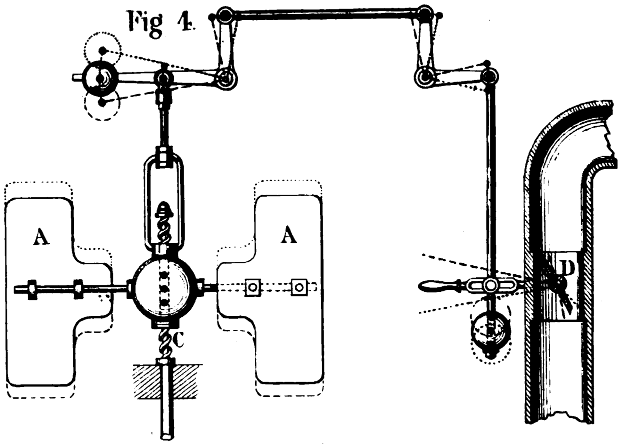


Fig 4.



Hick's Fly Governor. 2nd form

Fig. 5.

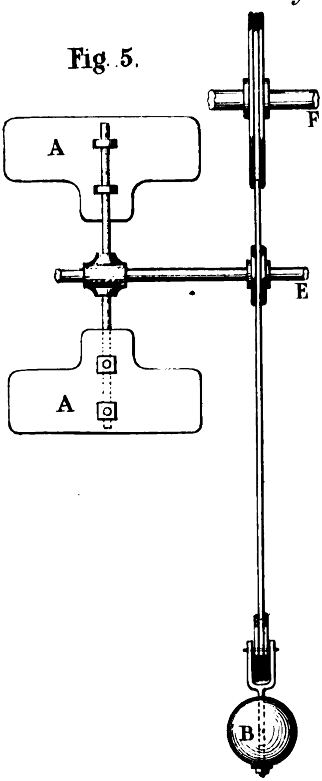
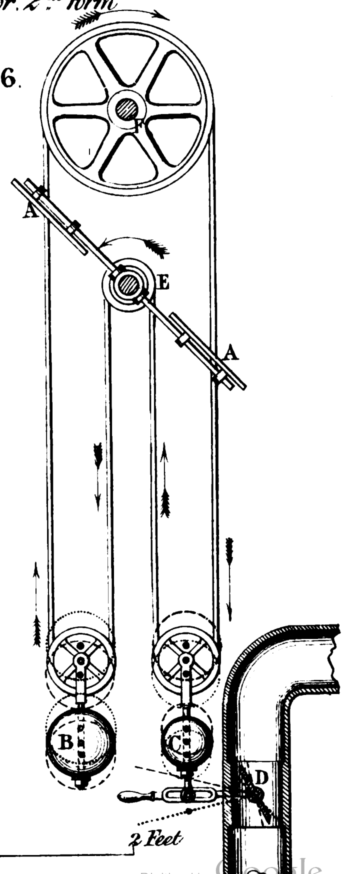


Fig. 6.



Scale 1/15th 0 1 2 Feet

(Proceedings Inst. M.E. 1853, Page 77.)

STEAM ENGINE GOVERNORS.

Siemen's Original Chronometric Governor.

Fig. 7. Elevation

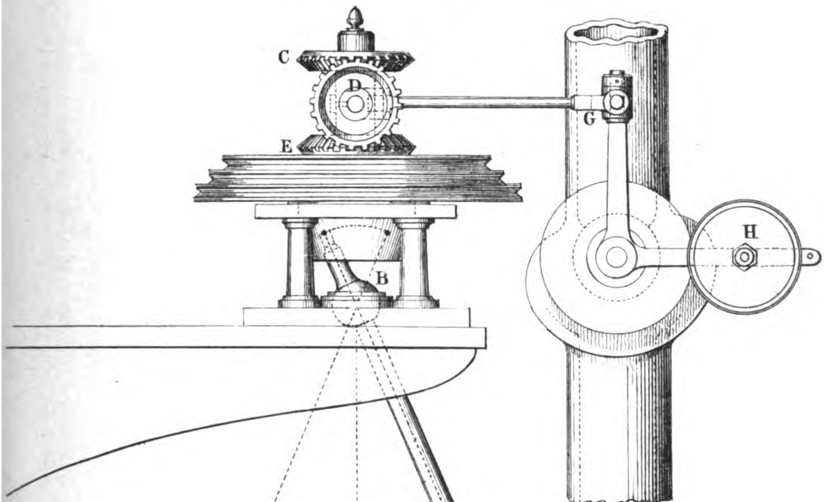
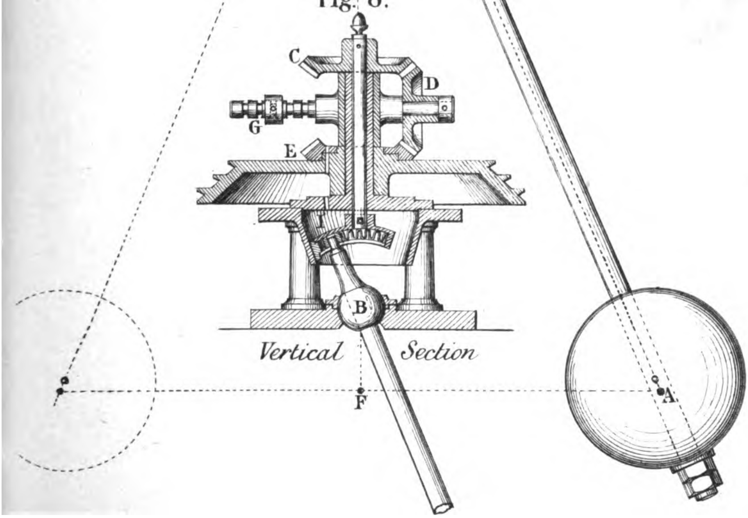


Fig. 8.



Vertical Section

Scale 1/10th 12 9 6 3 0 1 Foot

(Proceedings Inst. M.E. 1853, Page 79.)

STEAM ENGINE GOVERNORS.

Siemen's Improved Chronometric Governor.

Fig. 9. *Vertical Section.*

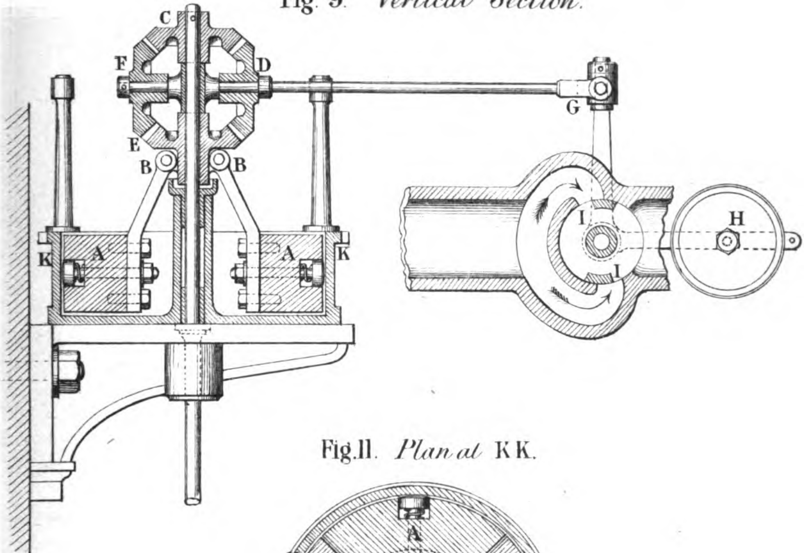


Fig. 11. *Plan at* K K.

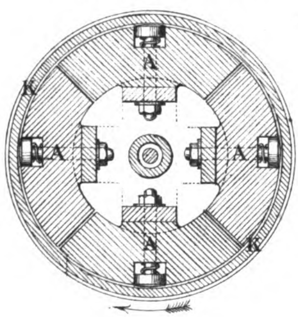
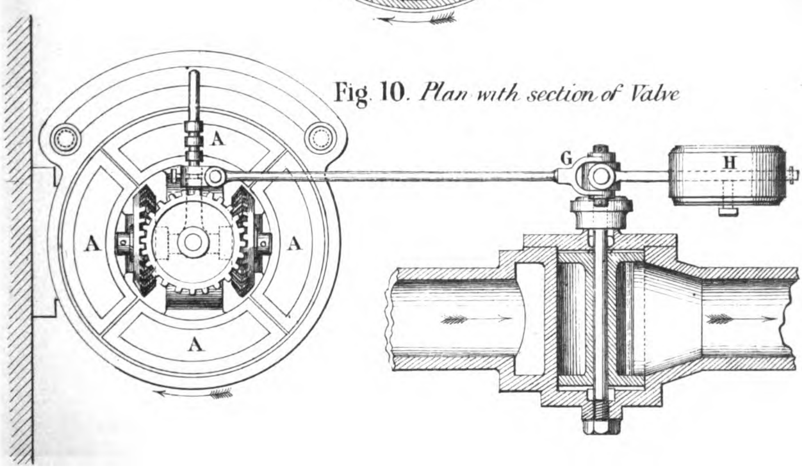


Fig. 10. *Plan with section of Valve*



Scale 1/10th 12 9 6 3 0 1 *Foot*

Fig. 1.
Section of Rolls.

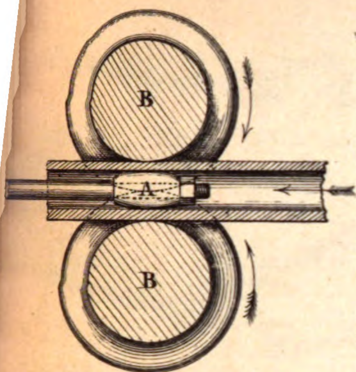


Fig. 2.
Elevation of Rolls.

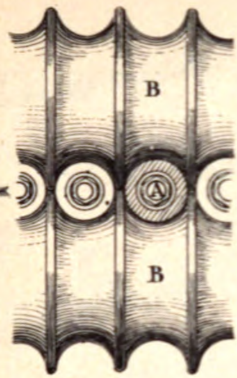
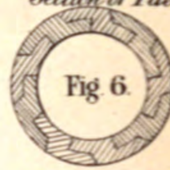


Fig. 5.
Section of Bar.

Section of Pile.



Section of Axle.

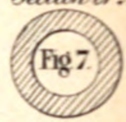


Fig. 3. *Longitudinal Section of Axle, rolled & welded.*

Fig. 4. *Longitudinal Section of Axle, with journals formed.*

Fig. 8. *Section of Finished Axle, with Parallel Journals.*

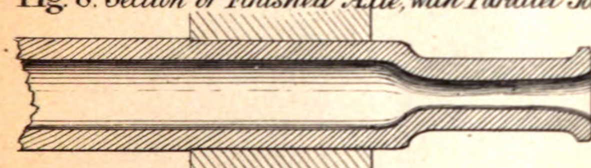
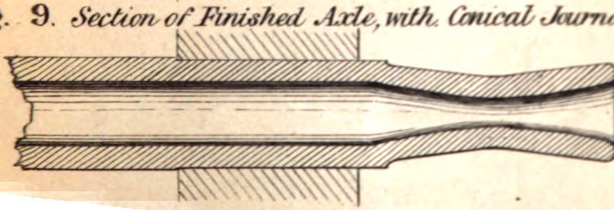
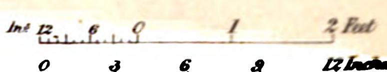


Fig. 9. *Section of Finished Axle, with Conical Journals.*



Scale 1/20th Figs. 1 to 4

Scale 1/8th Figs. 5 to 9



ceedings Inst. M.E. 1853, Page 89.)

Experiments on Hollow and Solid Axles

Fig. 10. Fracture of Solid Axle.

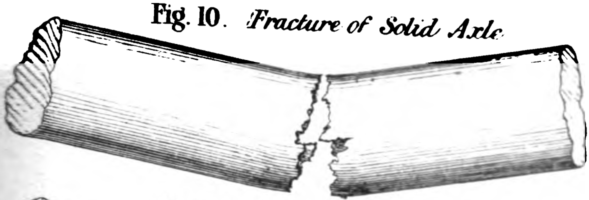


Fig. 11. Section of fracture.

Fig. 12. Fracture of Hollow Axle

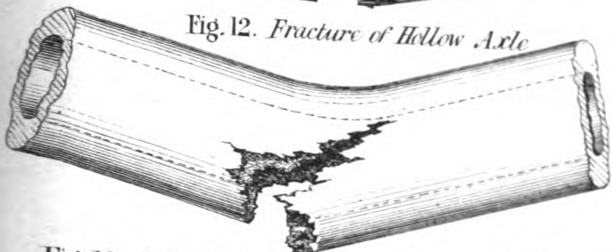


Fig. 13. Section of fracture

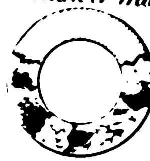


Fig. 14. Journal of Solid Axle

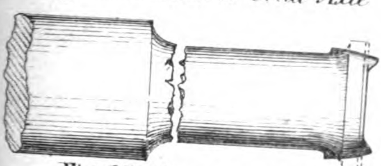


Fig. 15. Face of fracture

Fig. 16. Journal of Hollow Axle.

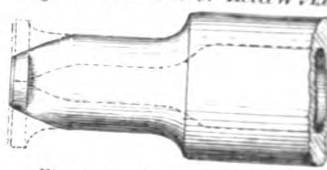
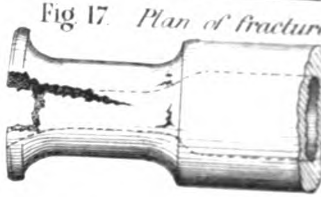


Fig. 17. Plan of fracture



Gauge for thickness of Hollow Axles.

Fig. 18. Side Elevation

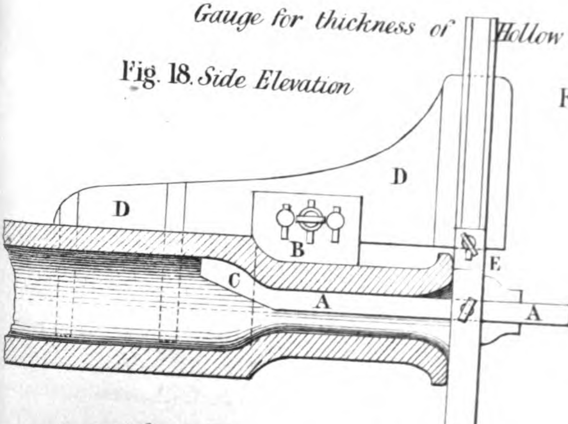
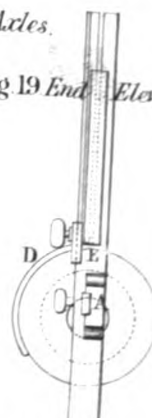


Fig. 19. End Elevation



Scale 1/6th 0 3 6 9 12 Inches

(Proceedings Inst. M.E. 1853. Page 92.)

IMPROVED JOINT CHAIR.

Plate 21

Fig. 1.

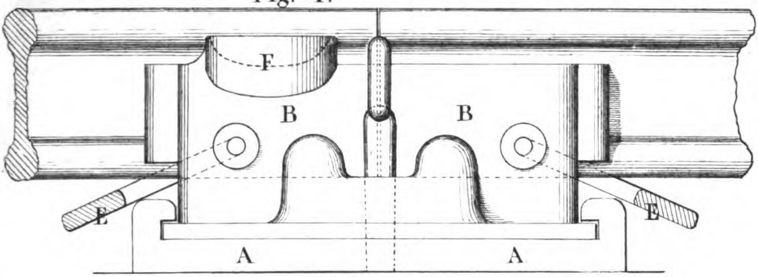


Fig. 2.

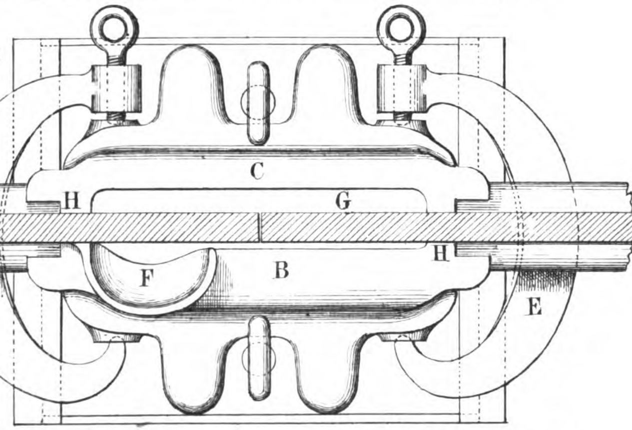


Fig. 3.

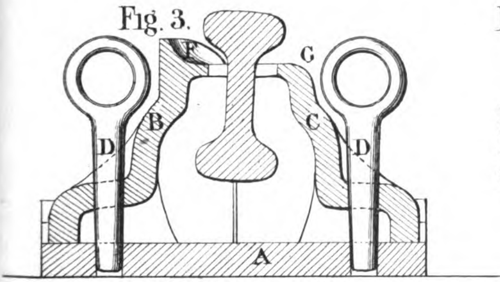


Fig 6.

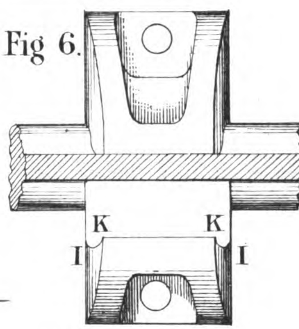


Fig. 4.

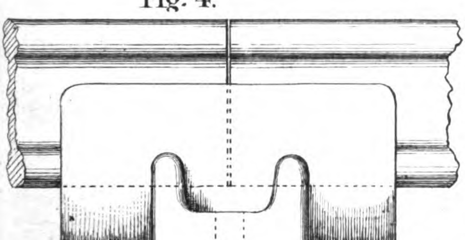
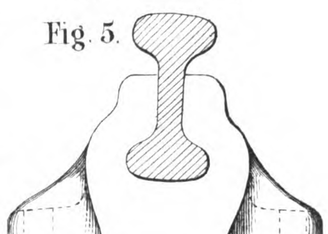


Fig. 5.



Scale 1/8th 0 3 6 9 12 *Inches*

IMPROVED JOINT CHAIR.

Portable Cupola & Fan

Fig. 7. *Elevation.*

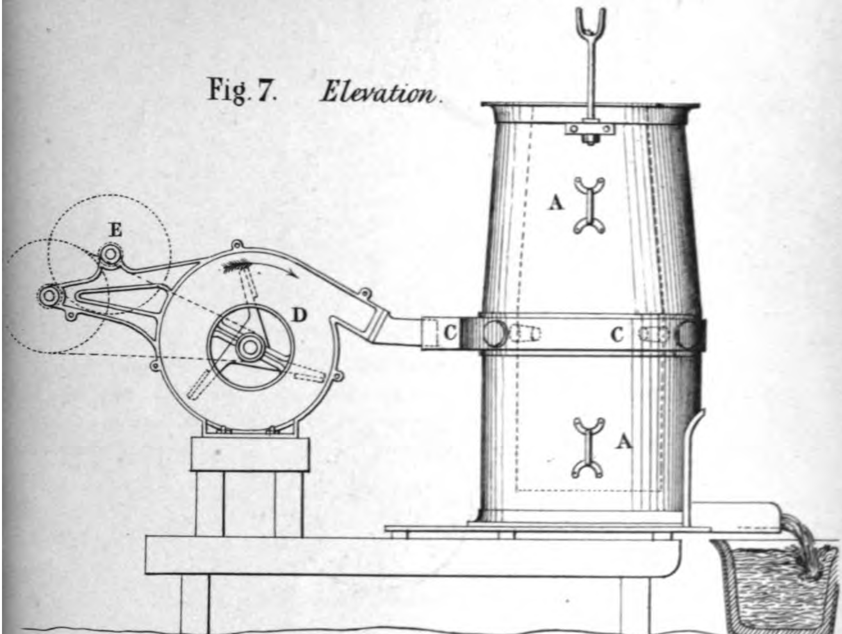
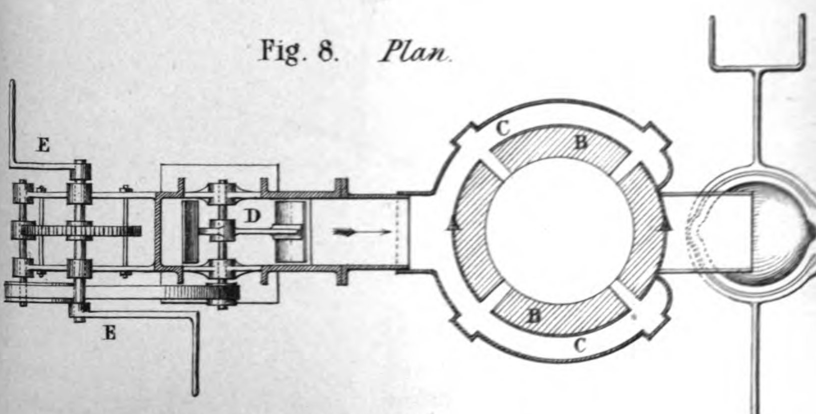
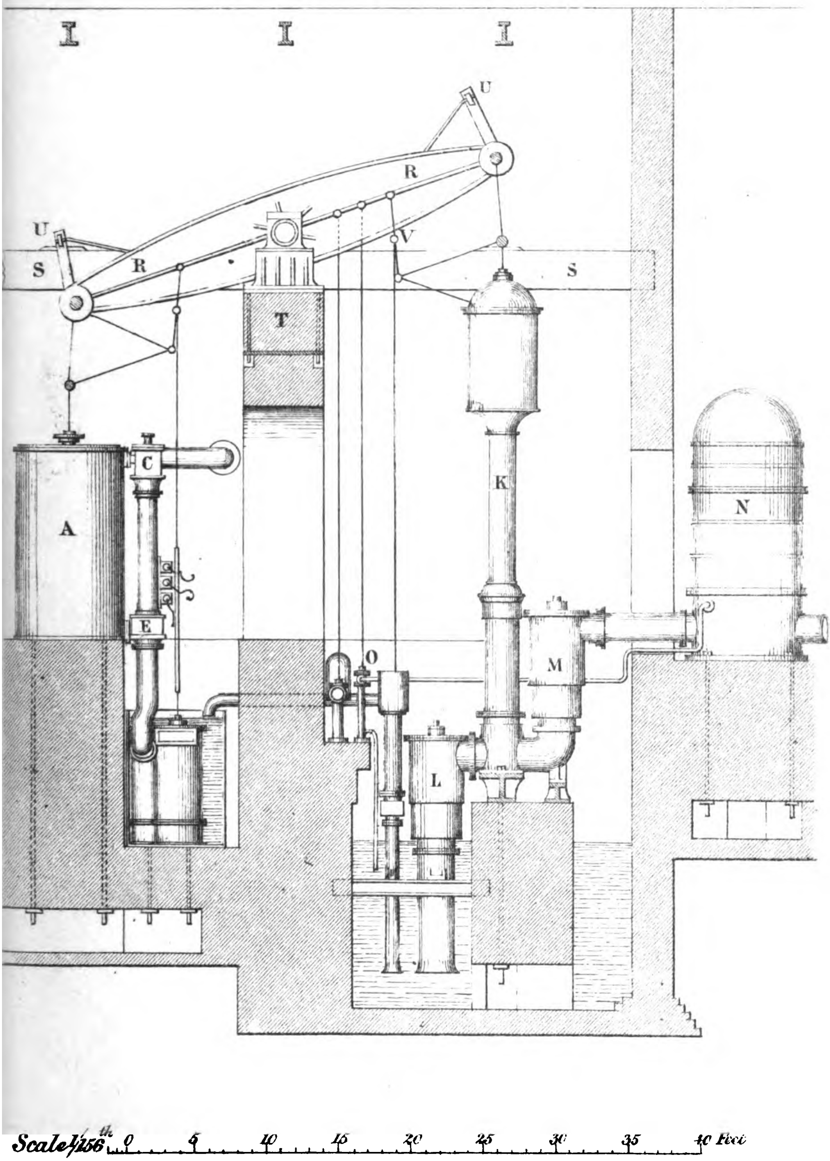


Fig. 8. *Plan.*



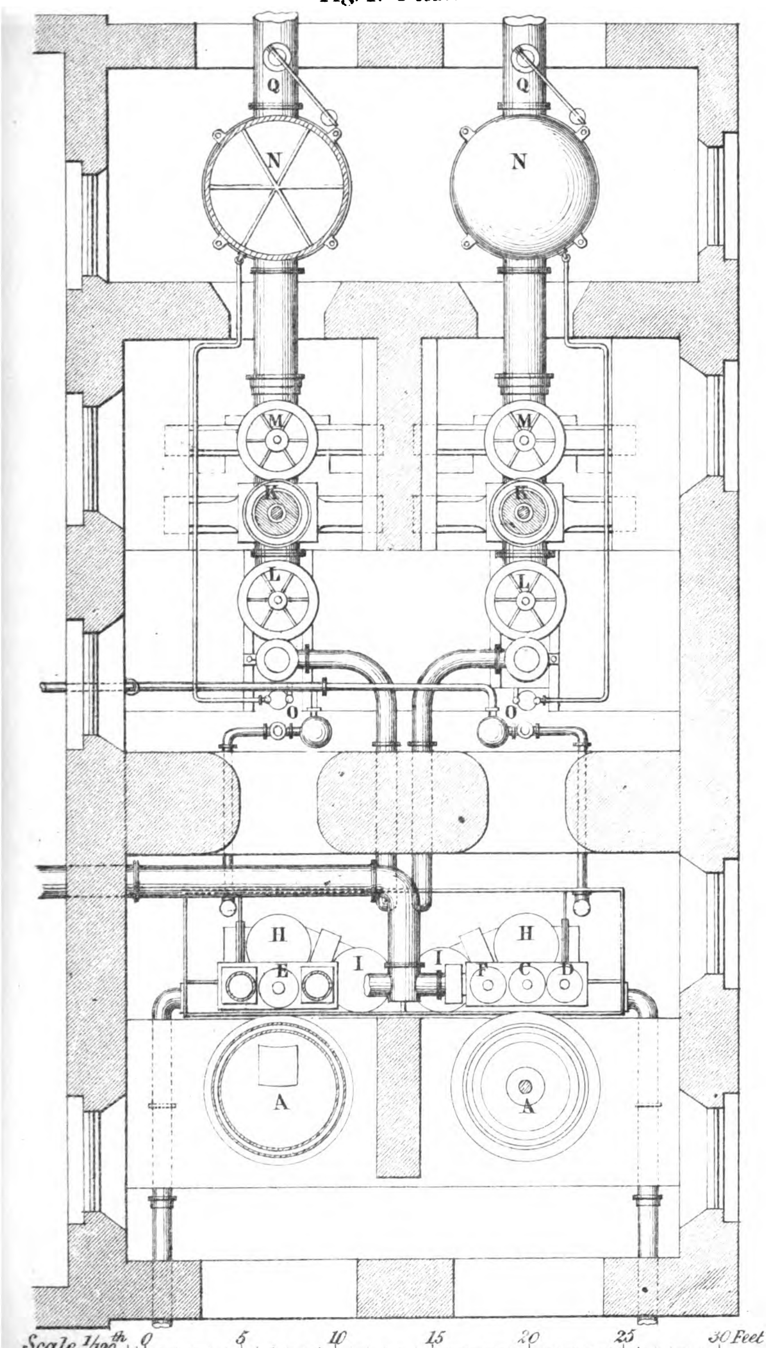
PUMPING ENGINE,
BIRMINGHAM WATER WORKS.

Fig. 1. *Elevation of Engine and Pump.*



(Proceedings Inst. M.E. 1853, Page 110.)

Fig. 4. *Plan*



(Procedings Inst. M.E. 1853, Page 110)

Fig 3. Section of Cylinder.

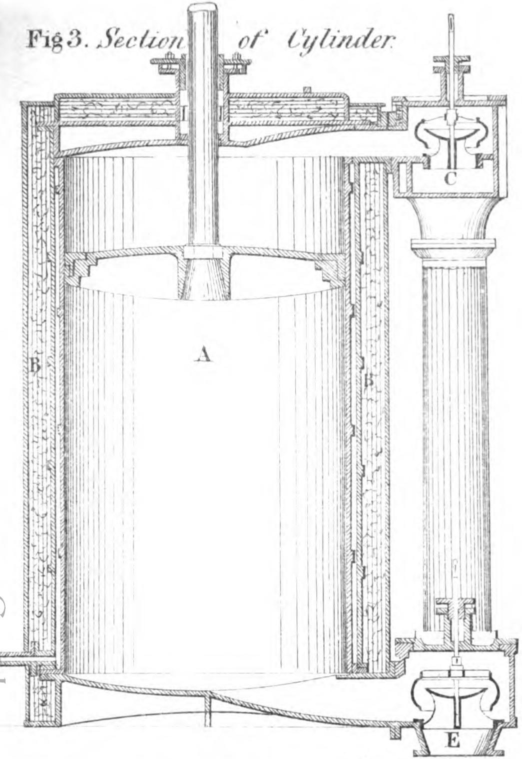
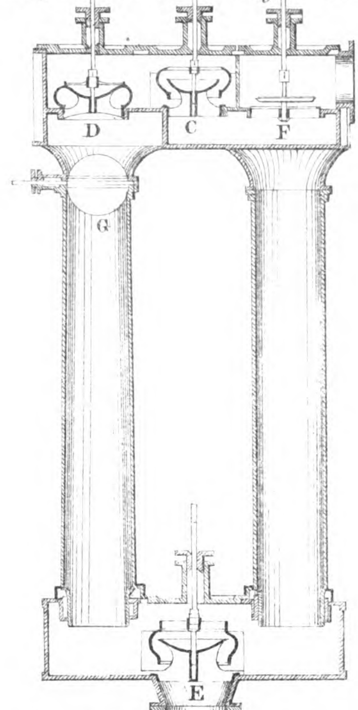
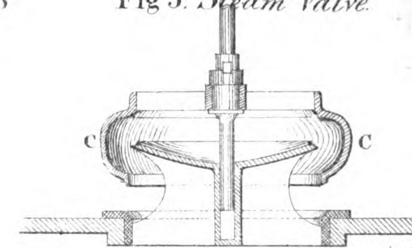


Fig 4. Section through Nozzles



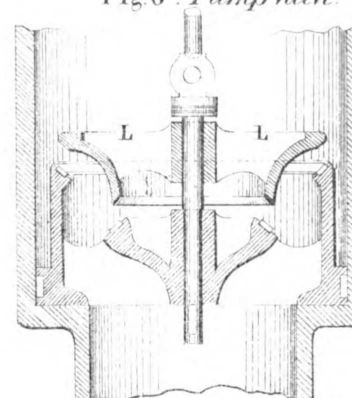
Scale 1/48th

Fig 5. Steam Valve.



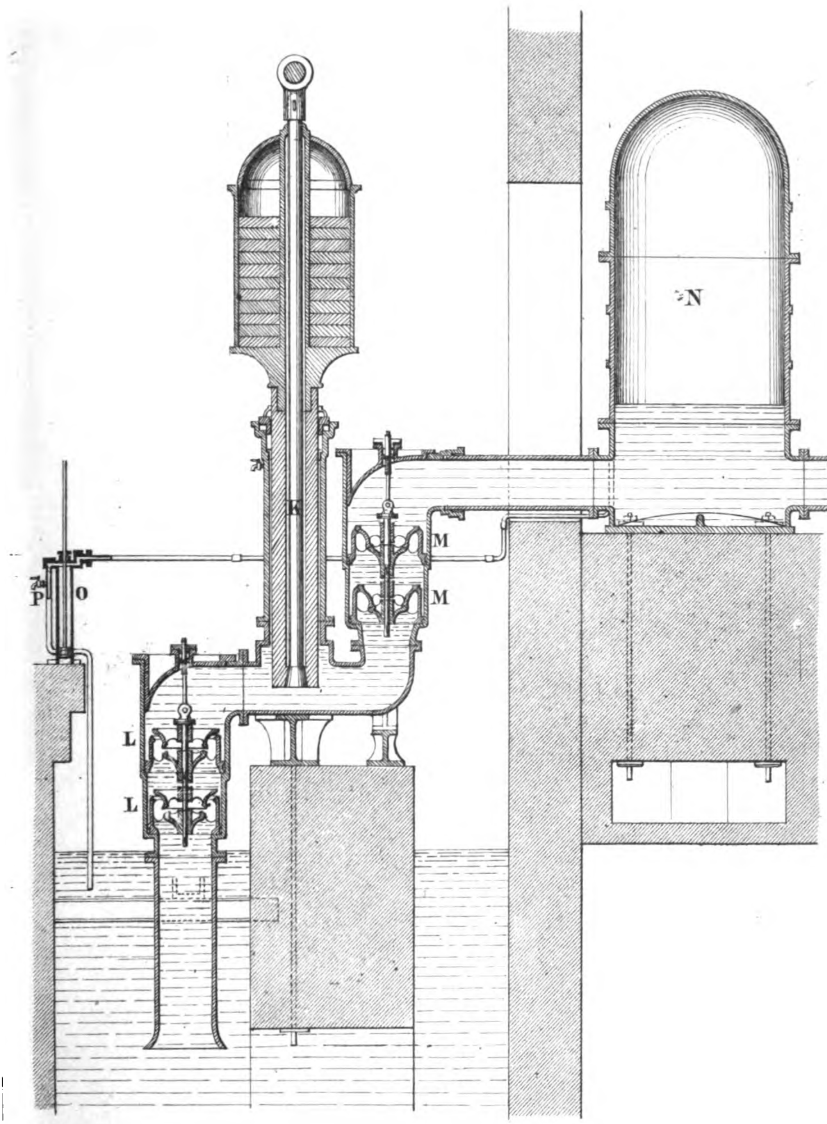
Scale 1/12th

Fig 6. Pump Valve.



Scale 1/24th

Fig. 7. *Longitudinal Section of Pump.*



Scale 1/96th 0 5 10 15 20 *Feet*

Fig 1. *Escape Water Valve applied to Horizontal Cylinder.*

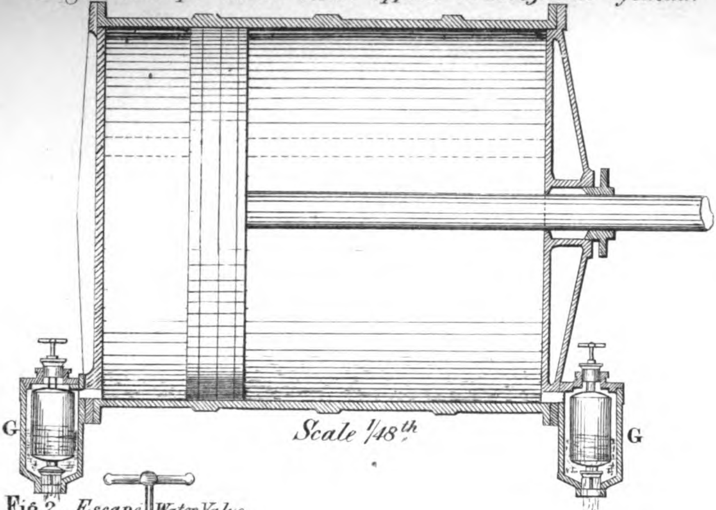


Fig 2. *Escape Water Valve.*

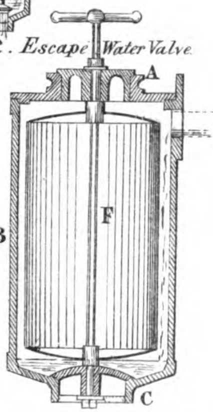


Fig 3. *Marine Engine Governor.*

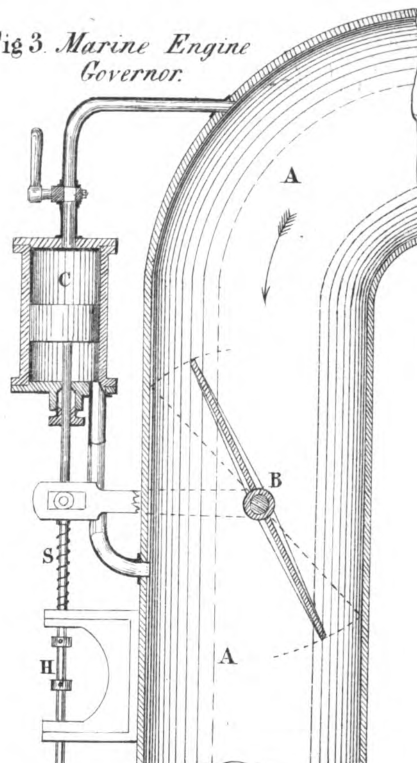
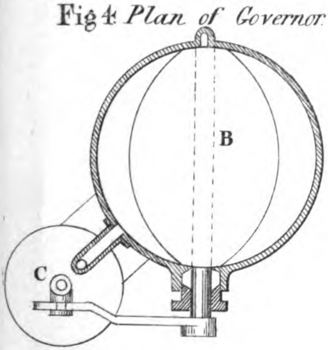


Fig 4. *Plan of Governor.*



Scale 1/16th 12 9 6 3 0 1 2 Feet.

COKING CRANE.

Fig. 1. *Elevation.*

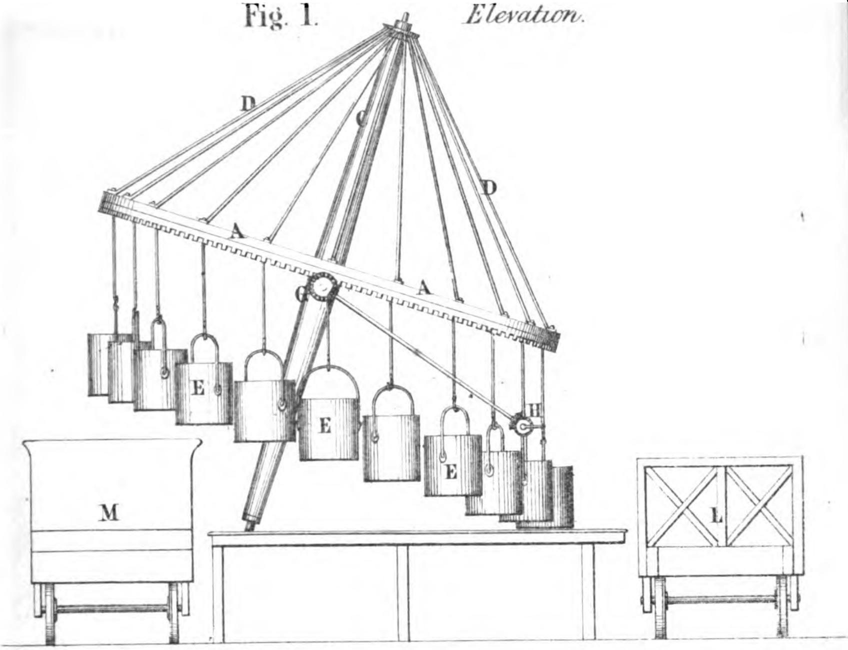
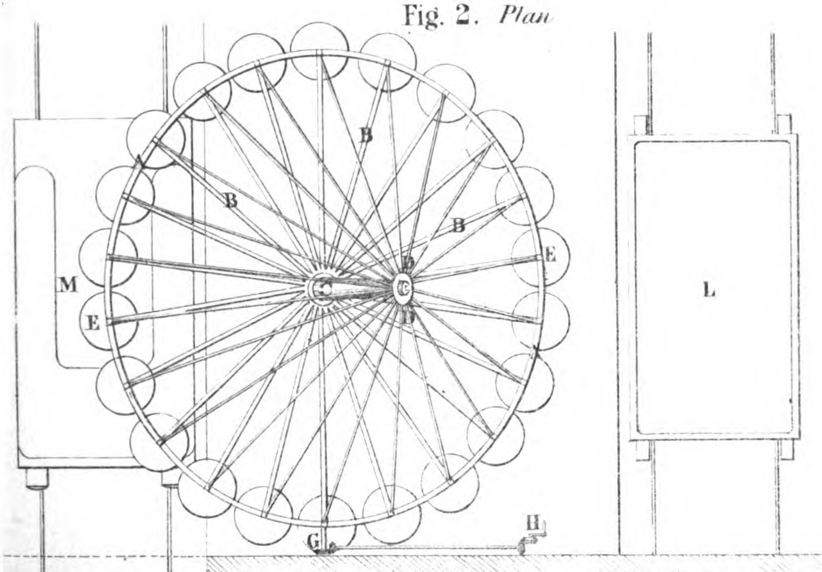


Fig. 2. *Plan*



Scale 1/96th 0 5 10 15 20 Feet

Sections of Roller Turntables.

Fig 1. Fig 3. Fig 4. Fig 5.

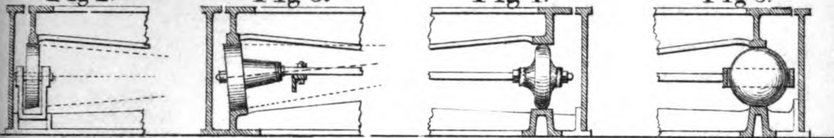
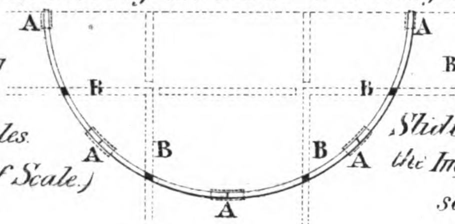


Fig 2. Plan showing the extent of bearing Surface.

A.A. Bearing Surface in Roller Tables. (Half Scale.)



B.B. Bearing Surface on Sliding Blocks in the Improved Table see Fig 10.

Fig 6. Section of Centre Bearing Turntable.

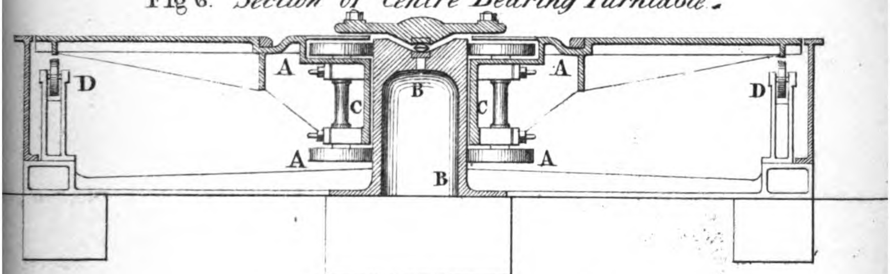
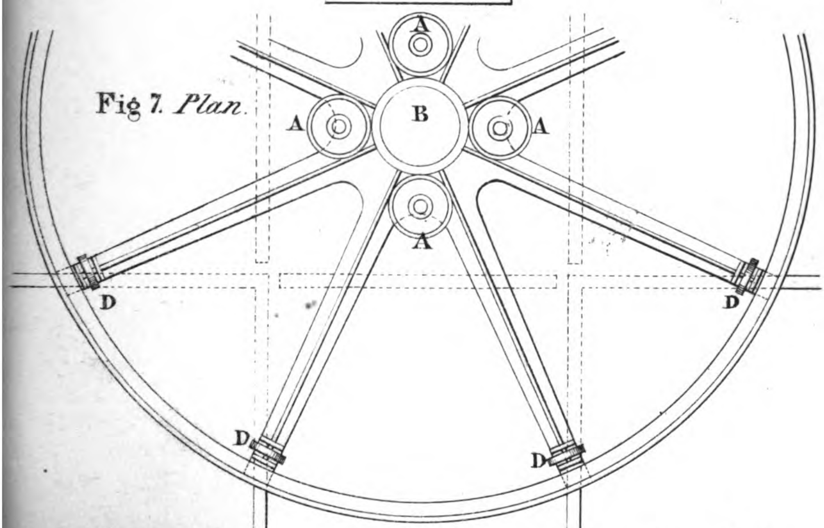


Fig 7. Plan.



Scale 1/36th 0 1 2 3 4 5 6 7 8 Feet

Plate 30

IMPROVED TURNTABLE.

Fig 8. *Section of Improved Turntable*

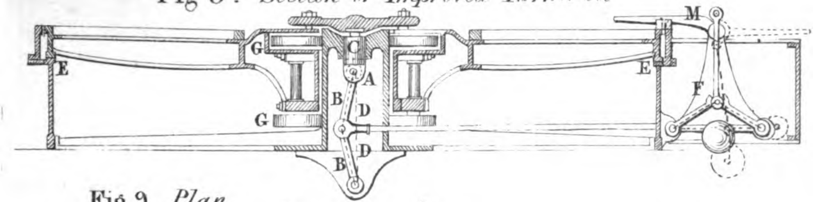


Fig 9. *Plan*

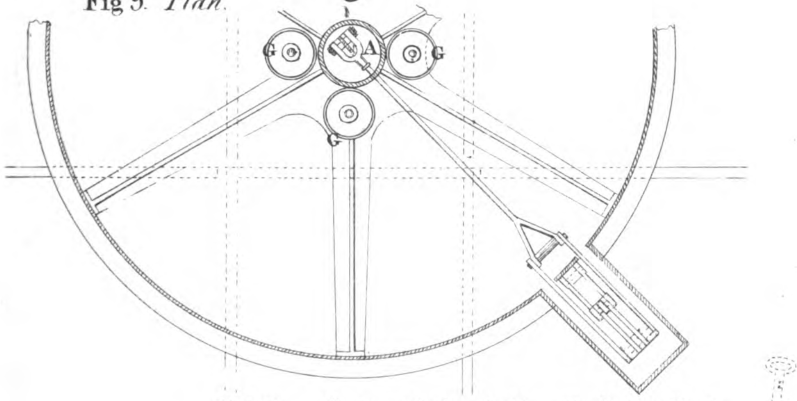


Fig 10. *Section of Turntable with Sliding Blocks.*

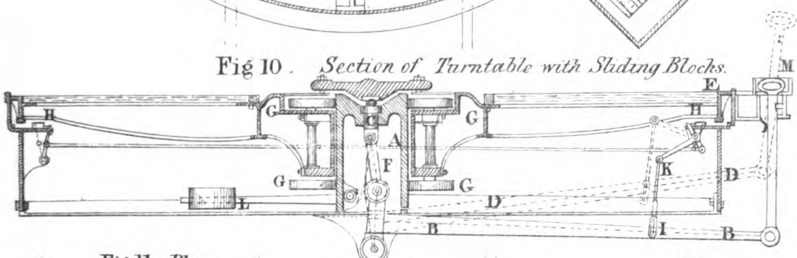
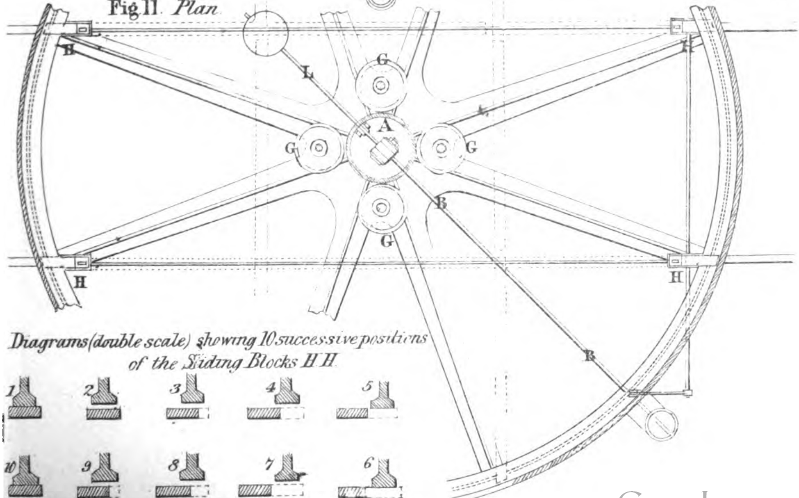


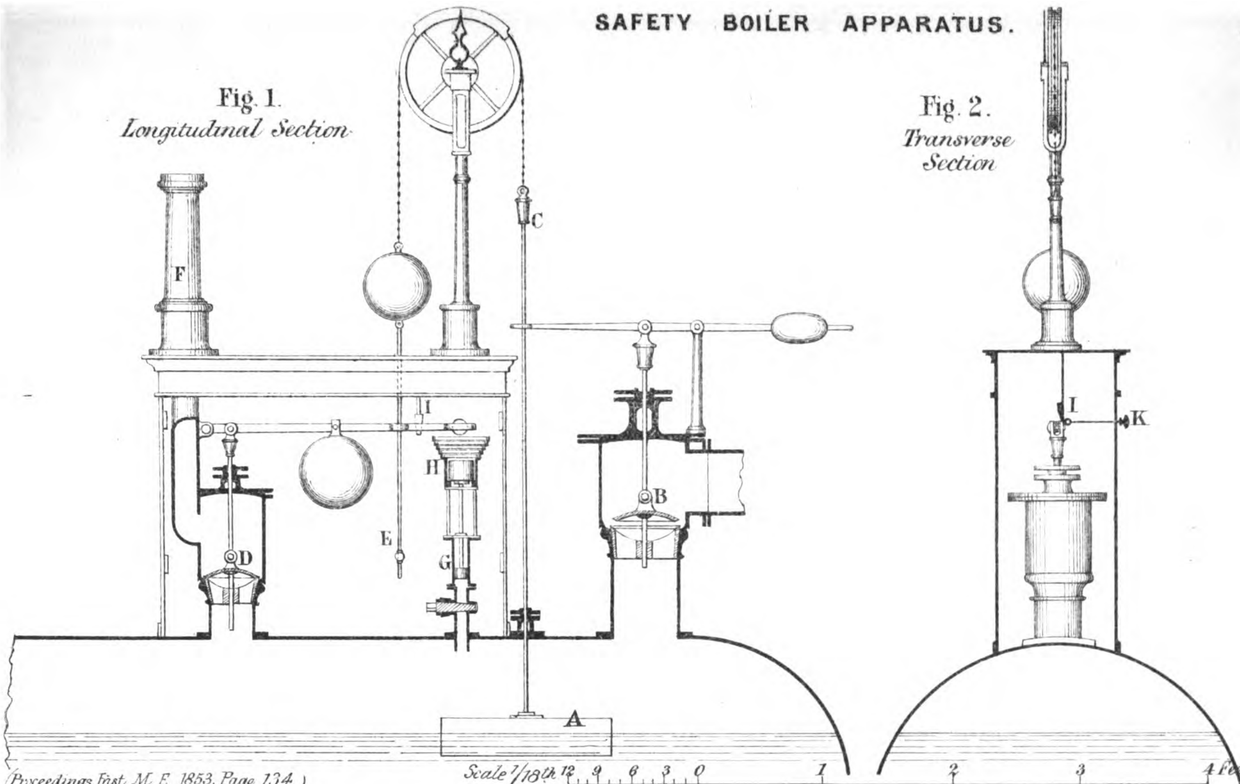
Fig 11. *Plan*



Diagrams (double scale) showing 10 successive positions of the Sliding Blocks H H

Scale 1/48th 0 1 2 3 4 5 6 7 8 9 10 *Feet.*

SAFETY BOILER APPARATUS.



(Proceedings Inst. M. E. 1853. Page 134.)

WINDING ENGINE.

Fig 1. *Section through Cylinder & Valves.*

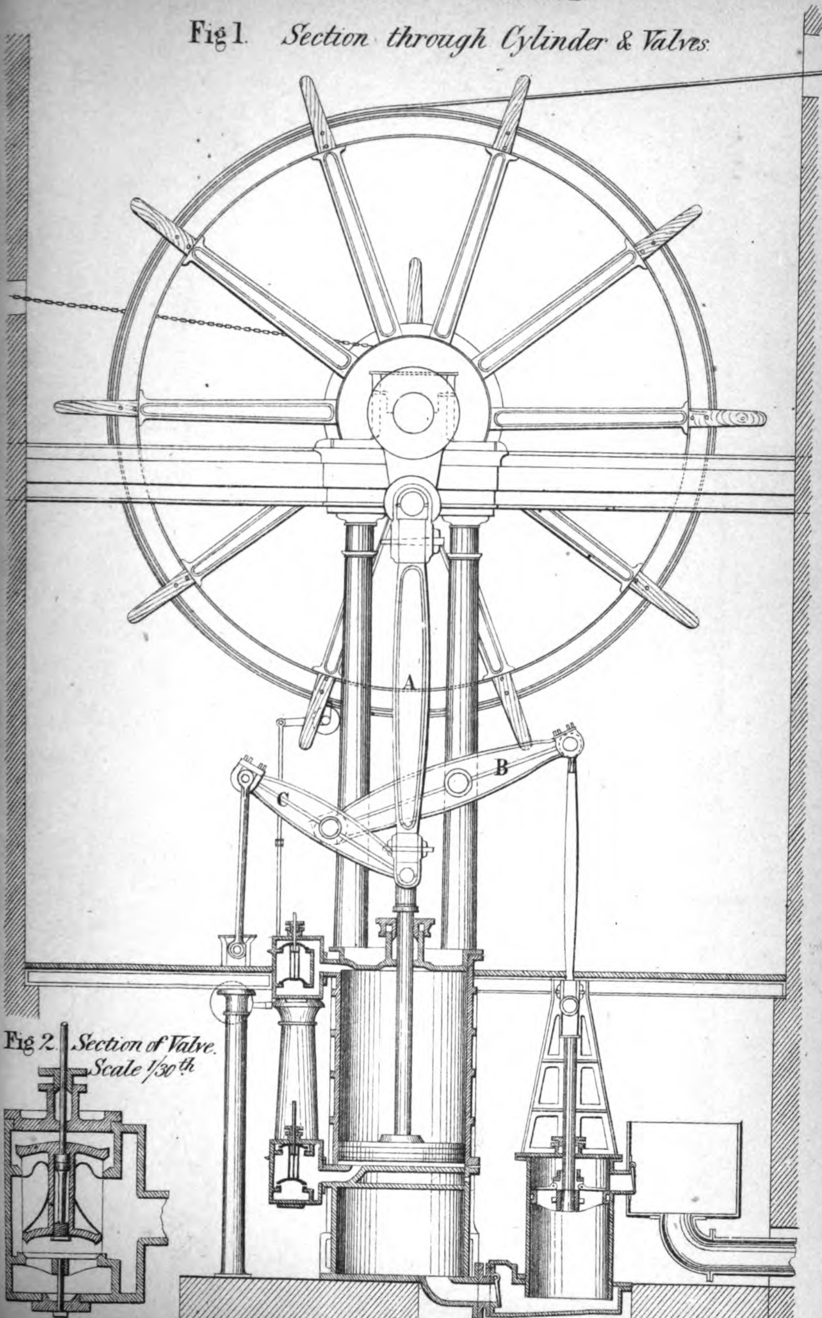


Fig 2. *Section of Valve. Scale 1/30th*

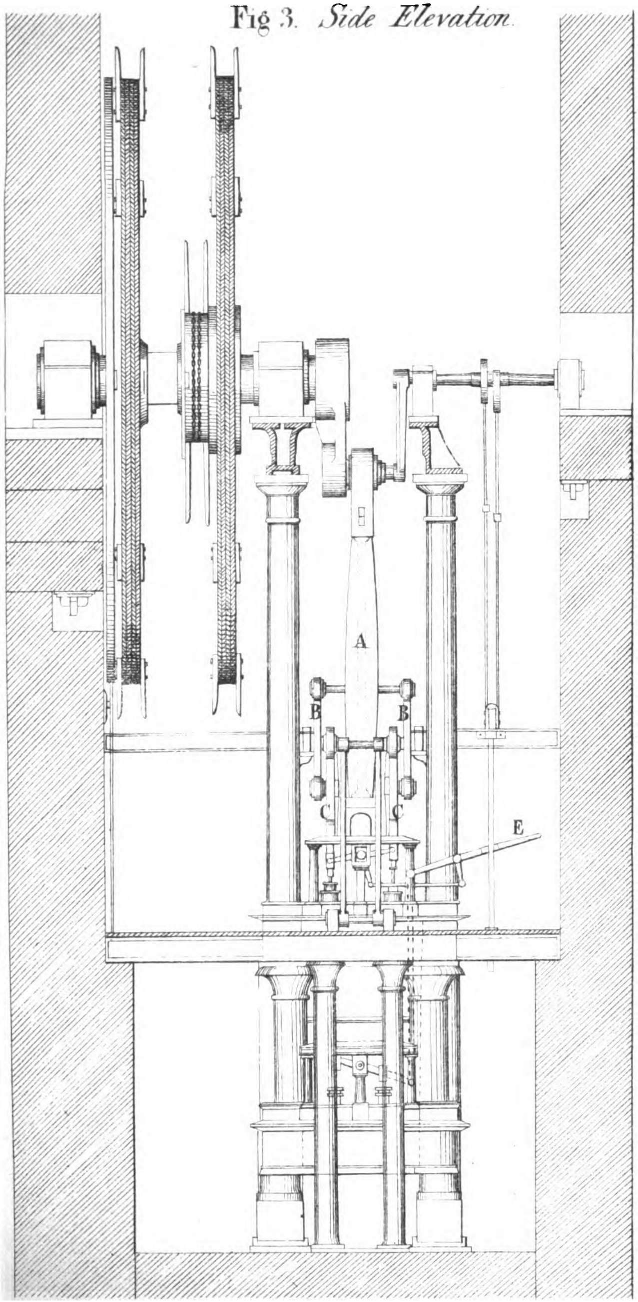
Scale 1/30th 0 5 10 15 20 Feet

(Proceedings Inst. M.E. 1853. Page 138.)

Plate 33.

WINDING ENGINE.

Fig 3. *Side Elevation.*



Scale 1/90th 0 5 10 15 20 Feet

Proceedings Inst. M.E. 1863. Page 138.)

CARTWRIGHT'S COMBING MACHINE.

1792.

Fig. 1.

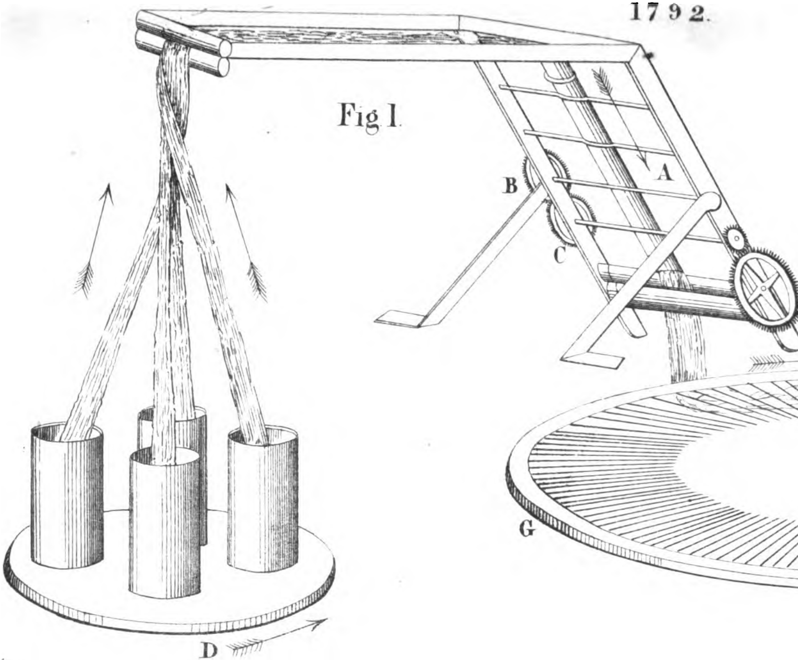
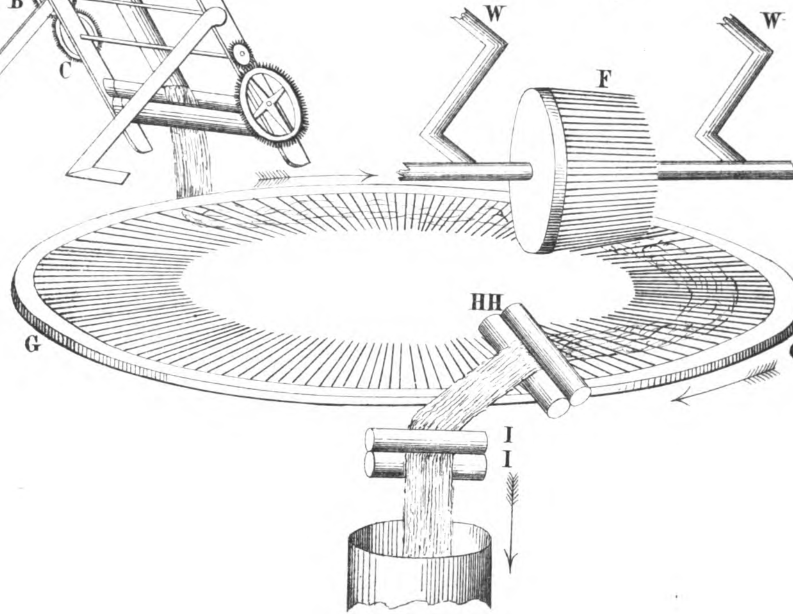
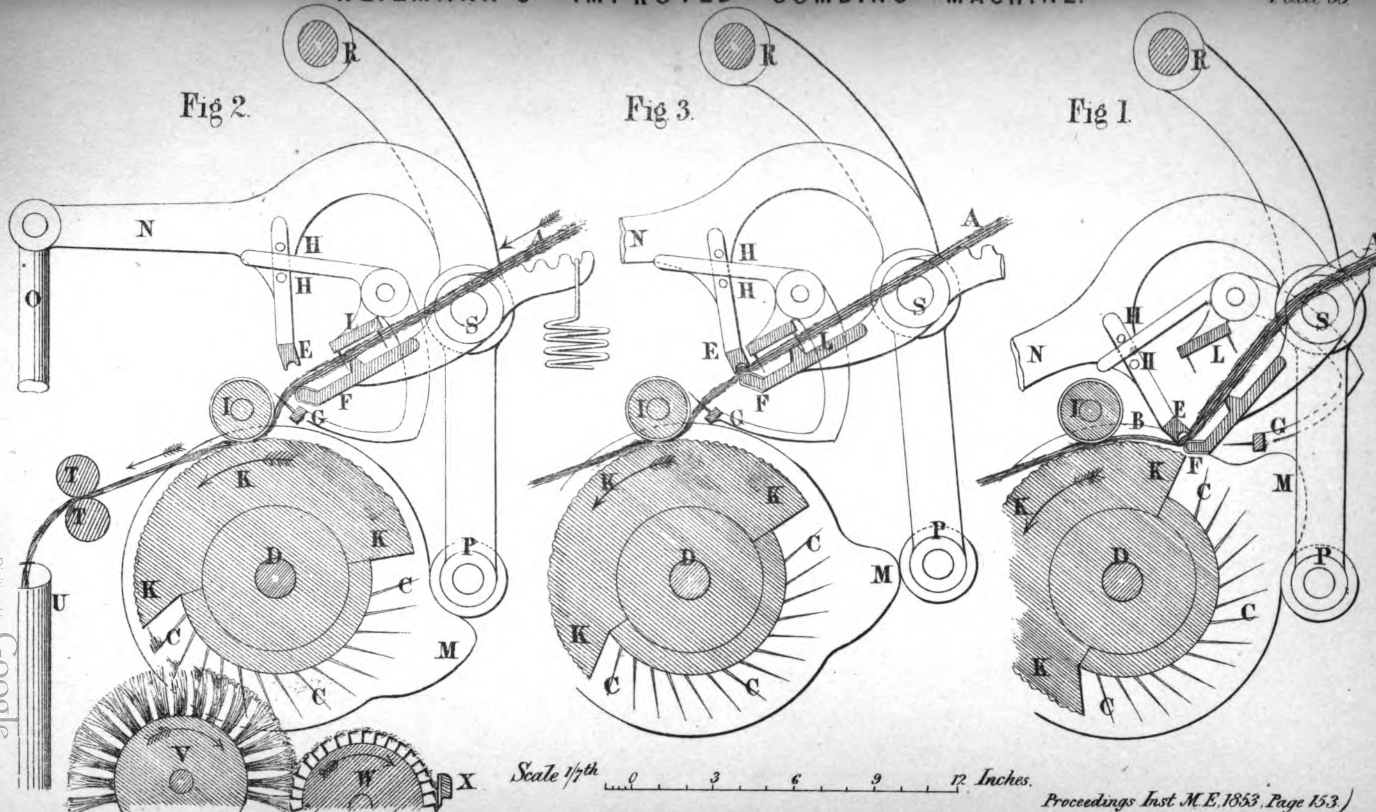


Fig. 2.



HEILMANN'S IMPROVED COMBING MACHINE.

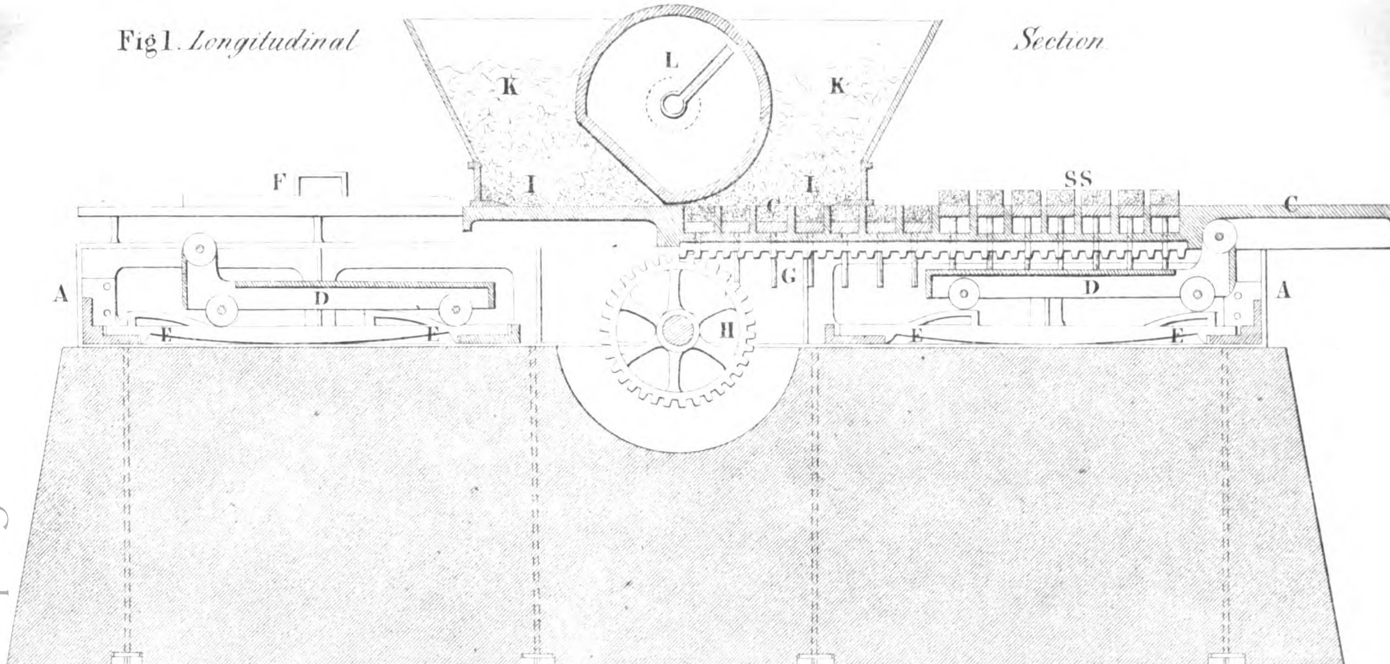


Scale 1/7th 0 3 6 9 12 Inches.

Proceedings Inst M.E, 1853, Page 153.)

DRY-CLAY BRICK MAKING MACHINE.

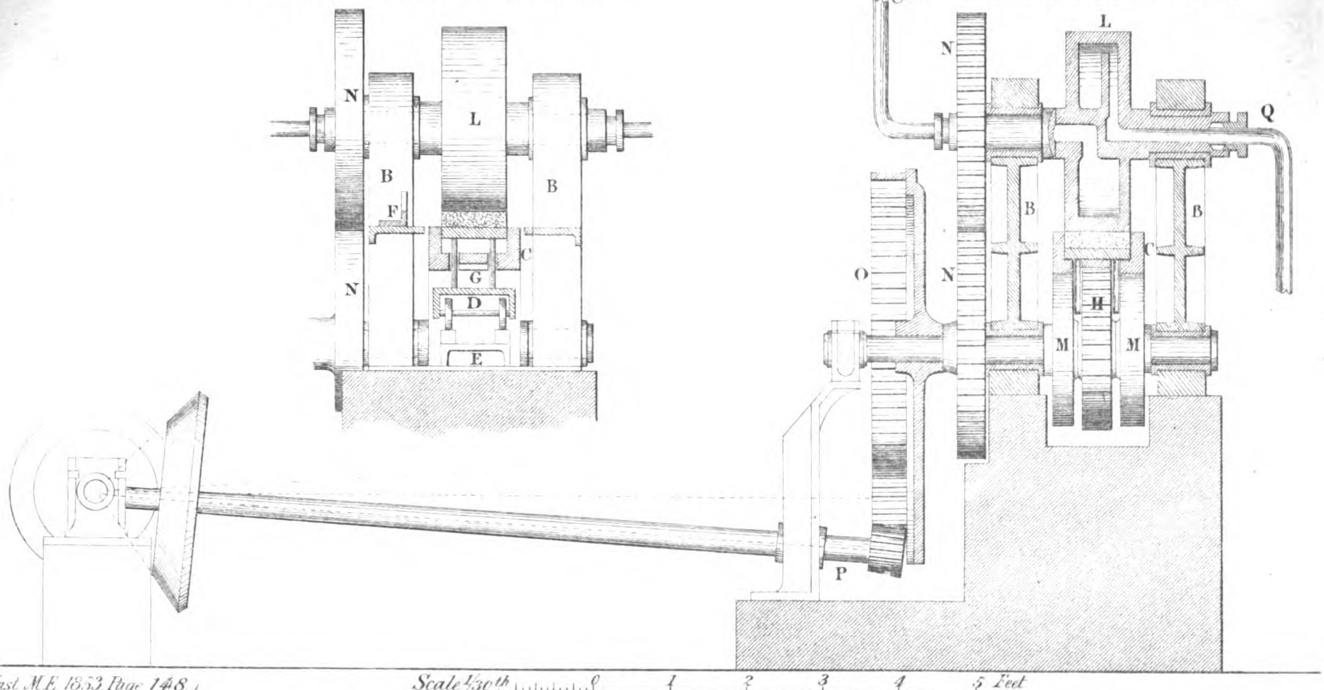
Fig 1. Longitudinal Section



DRY-CLAY BRICK MAKING MACHINE.

Fig. 3. *Transverse Section at S.S.*

Fig. 2. *Transverse Section at Centre*



WATER METER.

Fig 1. *Sectional Plan*

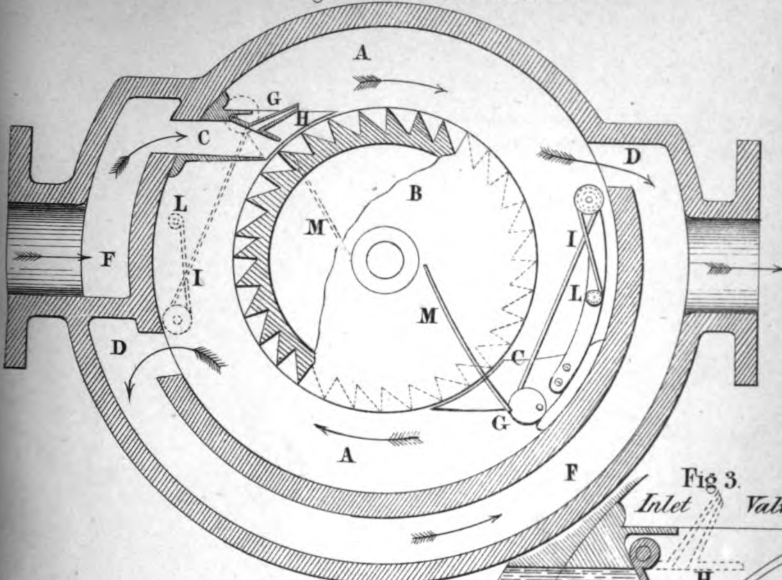


Fig 3. *Inlet Valve.*

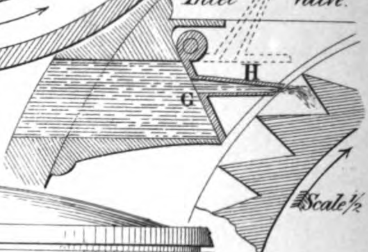
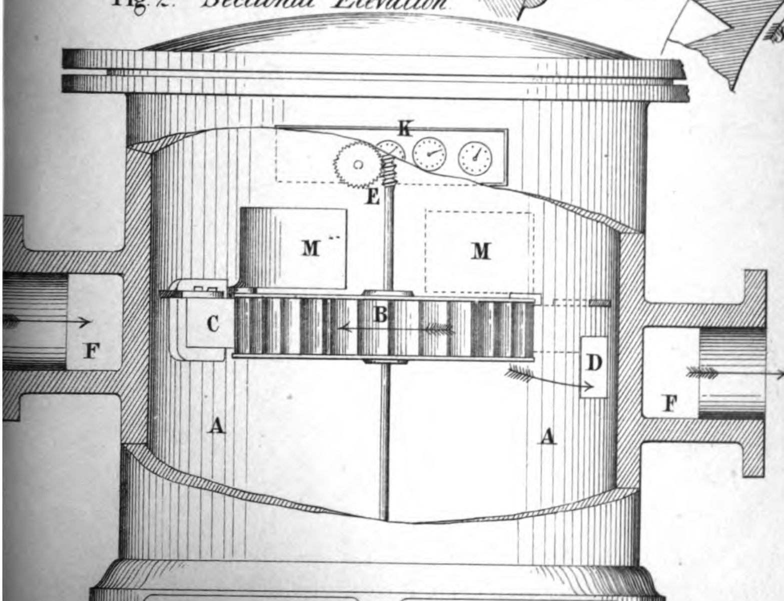


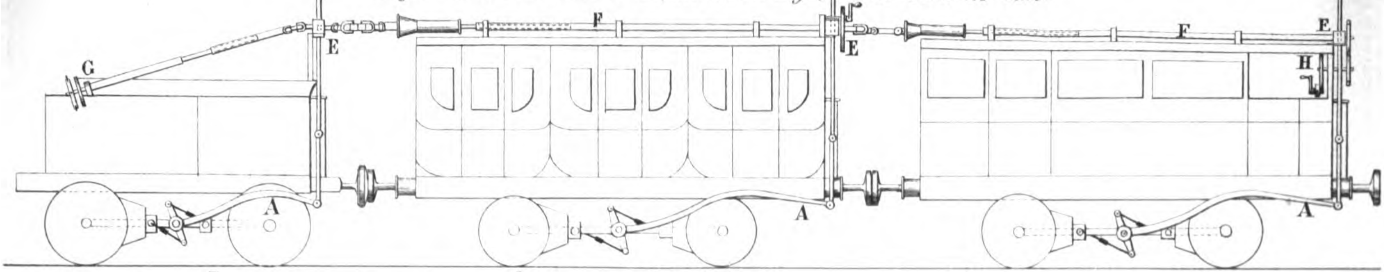
Fig. 2. *Sectional Elevation*



Scale ¼th 0 1 2 3 4 5 6 7 8 9 10 Inches.

NEWALL'S RAILWAY BREAK.

Fig 1. *Side Elevation of Tender, Carriage, and Guards Van.*



Scale 1/96th size

Fig 2 *End of Tender*

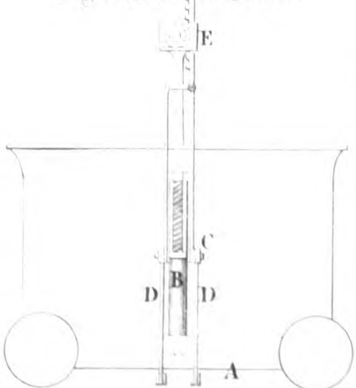


Fig 3 *Side Elevation of Coupling*

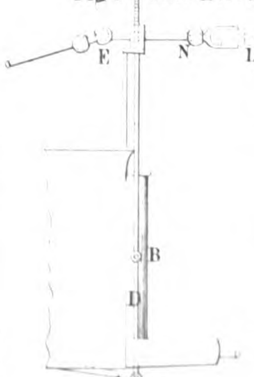
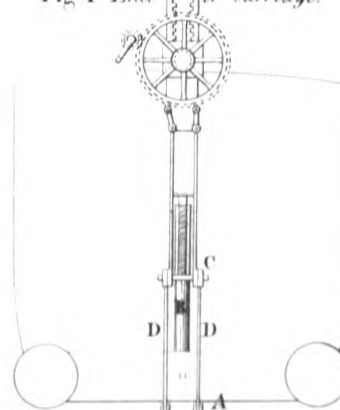


Fig 4 *End of Carriage.*



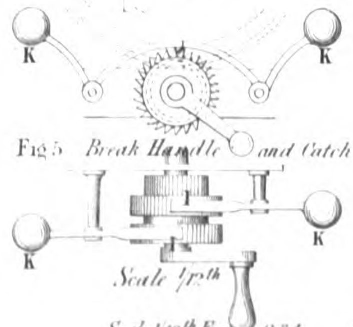


Fig 5 *Break Handle and Catch*

Scale 1/12th

Scale 1/48th Figs 2.3.4 0 1 2 3 4 5 6 *Feet*

(*Proceedings Inst. M. E. 1853. Page 158.*)

CENTRIFUGAL PUMP.

Fig 1.

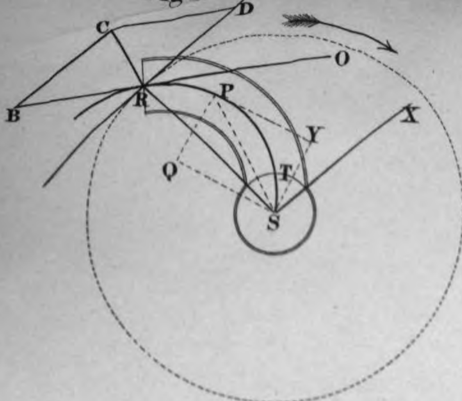


Fig 3.

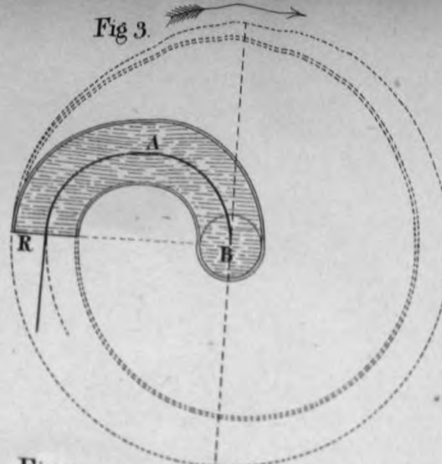


Fig 5.

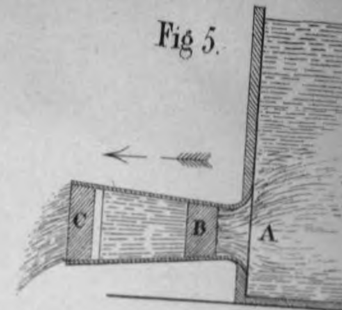


Fig 2.

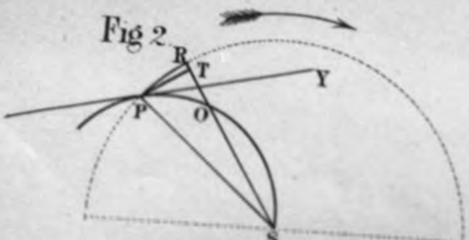


Fig 4.

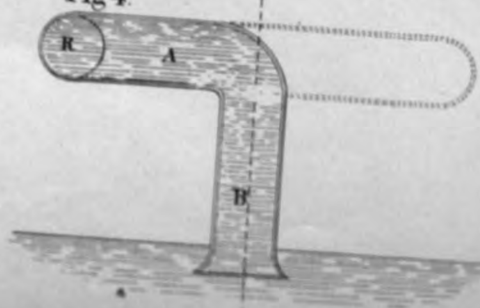
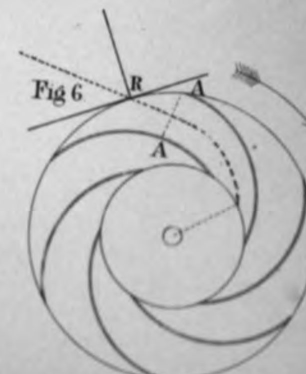


Fig 6.



(Proceedings Inst. M.E. 1853, Page 165.)